

DECLARATION

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WINDOW GLASS HAVING ELECTROMAGNETIC SHIELDING CHARACTERISTIC

Background of the Invention

1. Field of the Invention

This invention relates to various window glasses, each having an electromagnetic shielding characteristic, for use in windows of buildings, vehicles such as automobiles and trains, and furniture and fixtures such as partitions and boxes.

2. Description of the Related Art

When the personal portable equipments applied with radio techniques are put to practically use within the scope of the law, there are required electromagnetic shielding for the interiors of the buildings or the vehicles for the purpose of reclamation of the frequencies, countermeasures for the radio wave interference, and security means for telecommunication.

For example, when any one of the business establishment-use PHS (independent enterprise-one indoor for exclusive use) and the wireless-LAN (radio wave LAN) are produced in a specified building, the technical standard and the contents of the techniques of producing them are disclosed, and also the analyzing/measuring devices are on the market, thereby enabling the communication information used the indoor service to be easily accessed from the outside, then to be monitored.

It is difficult to protect the telecommunication information by the use of encipherment or the like in the

PHS terminals which serve as public use, so that the methods for ensuring the security generally include only electromagnetic shielding for preventing the radio wave from being leaked outside the telecommunication area.

Moreover, usable frequency channels are subjected to restriction, so that securing the number of the usable PHS terminals as much as possible requires the electromagnetic shielding for confining the radio wave according to the usable area.

Besides, the electromagnetic shielding is required in order to prevent portable telephones or the like from operating in cases where e.g. when the electromagnetic wave interferes in the medical equipments and with the patients to cause functional diseases in a medical field such as hospitals, when the use of the portable telephones troubles the others in the public area such as the restaurants and the vehicles, or when the audience is required to keep quiet in the concert hall or the like.

There has been widely used the electromagnetic shielding for the radio waves, and then there has been followed the studies that the electromagnetic shielding is realized by metal plates, metal meshes and wave absorbing materials.

For example, in the building, the floors each including deck plates and other steel plates conventionally realize sufficient electromagnetic shielding, and closely lining copper foils or metal meshes on the external wall surfaces and the partitions between tenant rooms results in

effective electromagnetic shielding even for the microwave band.

On the contrary, the window glass has difficulty in electromagnetic shielding in spite of the permeability of the light. For this reason, there are cases in which the window panes of the respective rooms of the building are changed to the walls and then are made of the electromagnetic shielding construction for the purpose of the electromagnetic shielding, thereby providing living environment with no visibility and with confinement feeling.

Furthermore, the metal wires have been incorporated into the window glass in order for the window glass to be composed of an electromagnetic shielding construction; however the electromagnetic shielding for the radio wave (frequency band of 1.9 GHz) for use in, for example, the PHS requires the fine wire mesh of about 0.1 mm, thereby causing the transparency to be degraded although realizing the electromagnetic fielding, with no comfortable living environment.

It is practically used to laminate thin vapor deposition films each made of a metal such as tungsten and aluminum entirely on the surface of the glass or inside the glass as another example of providing the electromagnetic shielding construction for the window glass. It is known that the above method attains a maximum attenuation of 20 to 30 dB ($= 1/100$ to $1/1000$) for the PHS (1.9 GHz) and the wireless LAN (2.45 GHz), which reduces an amount of visible light merely by 30 to 35% to eliminate the visibility

restriction.

This method, however, enables the radio wave, which is penetrated from outside the building, to be shielded to some extent for all the range of the frequency bands without degrading the openness of the building naturally illuminated, which unexpectedly provides electromagnetic shielding for ordinal telecommunication which should not be shielded, for example, everyday telecommunication such as public portable telephones, pocket pagers, various kinds of broadcasts, police or fire fighting urgency traffic, and codeless telephones.

It is therefore an object of the invention to provide a window glass having an electromagnetic shielding characteristic, which is capable of realizing electromagnetic shielding while selecting only a necessary frequency band of the radio wave, without degrading the natural illumination and the visibility, and also eliminates the need for energizing and grounding a gap portion between the electromagnetic shielding materials such as metal sashes of the window frame by the conductor.

Summary of the Invention

To attain the above object, according to a first aspect of the invention, there is provided a window glass having an electromagnetic shielding characteristic, wherein linear antenna elements each having such a length as to cause a radio wave, which is to be shielded, to be resonated are arranged on a surface of a glass or between glass plates taking account of an electromagnetic field

reflection equivalent area (scattering opening area) or an electromagnetic field reflection equivalent volume (scattering opening volume), the linear antenna element causing the radio wave to be scattered to thereby be attenuated.

According to a second aspect of the invention, there is provided a window glass having an electromagnetic shielding characteristic, wherein the linear antenna element is of an end portion open type, of which one side extending from a center thereof, having a length (electrical length) which is identical with the $1/4$ wavelength ($1/2$ wavelength in the case of a straight type one) of the radio wave to be shielded, and wherein the linear antenna element is of a ring line type, of which surrounding length (electrical length) is identical with the wavelength of the radio wave to be shielded.

According to a third aspect of the invention, there is provided a window glass having an electromagnetic shielding characteristic, wherein the linear antenna element is composed of a plurality of kinds of linear antenna elements for shielding a plurality of frequencies, in which two or more kinds of linear antenna elements different in size and shape from one another are arranged so as to be combined, wherein the linear antenna element is composed of a plurality of kinds of linear antenna elements for shielding a plurality of frequencies, in which an end portion open type linear antenna element and a ring line type linear antenna element, wherein the linear antenna

element is composed of a plurality of kinds of linear antenna elements for shielding a plurality of frequencies, in which an end portion open type linear antenna elements different in length from one another are combined, and wherein the linear antenna element is composed of a plurality of kinds of linear antenna elements for shielding a plurality of frequencies, in which a ring line type linear antenna element different in length from one another are combined.

According to a fourth aspect of the invention, there is provided a window glass having an electromagnetic shielding characteristic, wherein the end portion opening type linear antenna elements are arranged in such a manner that respective side ends of one of the linear antenna elements is closed to centers of the others of the linear antenna elements adjacent to the one of the linear antenna elements, and wherein the end portion opening type linear antenna elements is partially of a ring line type.

According to a fifth aspect of the invention, there is provided a window glass having an electromagnetic shielding characteristic, wherein arrangement distances between the linear antenna elements are determined taking account of the relationship with an amount of attenuation.

According to a sixth aspect of the invention, there is provided a window glass having an electromagnetic shielding characteristic, wherein the linear antenna element has a volume resistivity of 5×10^{-8} ($\Omega \cdot m$), and wherein the linear antenna element is made of a material

which is superior in conductivity, durability, and weather-resistant, and contains a small amount of vitreous material.

According to the inventions of claims 1 to 3, the linear antenna element does not only reflect the electromagnetic wave energy at an area of a metal portion thereof, but also reflect the electromagnetic field at an area of the vicinity of the metal portion thereof. Then, arranging these linear antenna elements in space, or on the non-conductive material in two or three dimensions taking account of the electromagnetic field reflection equivalent area or the electromagnetic field equivalent volume realizes electromagnetic shielding, and further those linear antenna elements have gaps therebetween to thereby fail to cover all of the glass, which prevents natural illumination and visibility from being degraded.

Moreover, specifying the length of the patterned small linear antenna element causes the specified frequency to be shielded to thereby cause the other radio waves to pass therethrough, which prevents only the specified radio wave used in the building from being leaked to the outdoor without shielding the radio waves from which is required to be collected informations from the outdoor, such as radio waves for use in police or fire fighting urgency traffic, or television, to result in the improvement of the security and enable the frequency channel to be reclaimed.

As described above, the linear antenna element realize the electromagnetic shielding based on the reflection loss, whereas almost of the absorbed (received)

electric power is absorbed as heat loss, thereby eliminating the need for electrically connecting then earthing the linear antenna element with the metal sashes of the window frame, or the like, which results in the free setting without limits of the electrical connection.

Moreover, the actual radio waves are not uniform, i.e., variously inclined in plane of polarization; however, the linear antenna elements are formed of ring line type ones or end portion open type ones, thereby causing the radio waves having various planes of polarization to be shielded.

According to the inventions of claims 4 to 7, the linear antenna elements different in length from one another are combined to be regularly arranged, thereby enabling the waves having a plurality of frequency bands to be shielded, which causes the radio waves, which should be shielded, to be specified to the ones of a plurality of frequency bands to thereby result in wide application. For example, in the portable telephones, the electromagnetic shield can be realized for all the radio waves of two frequency bands of 900 MHz and 1.5 GHz.

According to the invention of claim 8, a portion of the linear antenna element having a high electric field and a portion of the another linear antenna element having a low electric field are closed to each other, thereby causing the portions each having a high electric field to be closed to each other, which prevents mutual interference between the elements, and further thereby causing the

density of the elements to be raised, which results in the improvement of attenuation.

According to the invention of claim 9, the end portion opening type linear antenna elements is partially of a ring line type, thereby increasing the reflection equivalent area to realize the high frequency band then result in the improvement of attenuation.

To ensure a large amount of attenuation amount, it is preferred that the linear antenna elements are arranged so as to be as closed as possible. On the contrary, arranging them so as to be more closed than necessary causes visual problem (eyesore). According to the invention of claim 10, it is found out that there is a relationship between the arrangement distance of the linear antenna elements and an amount of attenuation, determining the arrangement distance between the linear antenna elements based on a required amount of attenuation causes a gap between the linear antenna elements to be ensured in large amounts as much as possible, which provides better visibility on the surface of the glass.

To ensure a large amount of attenuation, it is preferred that the resistance loss of the linear antenna element is lowered as much as possible. For this reason, it is preferred to reduce the resistance loss by increasing the wire width. However, increasing the wire width of the linear antenna element degrades the optical transparency of the surface of the glass on which the above linear antenna elements are arranged. According to the invention of claim

11, the linear antenna element preferably has a volume resistivity of 5×10^{-8} ($\Omega \cdot m$) in a case where the linear antenna element has the wire width of about 0.5 mm, thereby causing the performance to be sufficiently ensured.

In a similar manner, to ensure a large amount of attenuation, it is preferable to introduce the element which is low in electrical resistance in order to reduce the resistance loss of the linear antenna elements. Copper, silver and gold are optimum for the material of the linear antenna element; however, gold is expensive, and copper is increased in resistance due to the oxidation. According to the invention of claim 11, introducing silver prevents the cost from being increased and eliminates the possibility for the resistance increasing due to the oxidation, and the mixture of a small amount, e.g. 5% of the vitreous material into the glass permits the vitreous material to be integral with the glass, thereby enabling the service life of the linear antenna element to be elongated to the same degree as the glass.

Brief Description of the Drawings

Fig. 1 is a perspective view showing a window glass according to a first embodiment of the invention;

Fig. 2 a front view of a main part of the window glass according to the first embodiment of the invention;

Fig. 3 is an explanatory view showing a case in which a linear antenna element is of a short-circuit type dipole;

Fig. 4 is a first explanatory view showing a

principle of an electromagnetic shielding method for the window glass according to the invention;

Fig. 5 is a second explanatory view showing a principle of an electromagnetic shielding method for the window glass according to the invention;

Fig. 6 is a front view of a window glass on which the linear antenna elements are arranged.

Fig. 7 is a perspective view showing a window glass according to a second embodiment of the invention;

Fig. 8 is a front view of the window glass according to the second embodiment;

Fig. 9 is a graph showing the experimental result of the characteristic of the window glass on which Y-like linear antenna elements are arranged, according to the invention;

Fig. 10 is an explanatory view showing an arrangement of cross type linear antenna elements;

Fig. 11 is an explanatory view of variant examples of the ring line type linear antenna elements;

Fig. 12 is an explanatory view of variant examples of the end portion open type linear antenna element;

Fig. 13 is a front view of a variant example of the end portion open type linear antenna element;

Fig. 14 is a perspective view showing a window glass according to a third embodiment of the invention;

Fig. 15 is a plan view of one example of the combination of the ring line type linear antenna element and the end portion open type linear antenna element;

Fig. 16 is a graph showing an electromagnetic shielding effect of the linear antenna element of Fig. 13;

Fig. 17 is an explanatory view showing variant examples of the combination of the ring line type linear antenna element and the end portion open type linear antenna element;

Fig. 18 is an explanatory view showing examples of the combination of the end portion open type linear antenna elements different in length from one another;

Fig. 19 is an explanatory view showing examples of the combination of the ring line type linear antenna elements different in length from one another;

Fig. 20 is an explanatory view showing examples of the combination of the linear antenna elements for three frequency bands;

Fig. 21 is an explanatory view of an experimental equipment for confirming a shielding performance of a gap portion between the window glasses;

Fig. 22 is a front view of an experimental device for confirming the relationship between the arrangement distance of the linear antenna elements and an amount of attenuation;

Fig. 23 is a longitudinal sectional side view of the experimental device for confirming the relationship between the arrangement distance of the linear antenna elements and the amount of attenuation; and

Fig. 24 is a graph showing an experimental result of confirming the relationship between the arrangement

distance of the linear antenna elements and the amount of attenuation.

Detailed Description of the Preferred Embodiments

Embodiments of the invention will be described hereinbelow in detail with reference to the drawings. Fig. 1 is a perspective view showing a window glass having an electromagnetic shielding characteristic according to a first embodiment of the invention. In Fig. 1, reference numeral 1 designates a window glass, and 2 sash frame. Linear antenna elements 5 each having such a length as to correspond to the frequency of a radio wave to be shielded are arranged regularly on the window glass 1 taking account of the electromagnetic field reflection equivalent area or the electromagnetic field reflection equivalent volume, whereby the linear antenna elements 5 attenuate the radio wave.

First, the basic principle related to the invention will be described hereinbelow. When a radio wave is incident onto a conductor piece placed in the air, the radio wave is partially reflected therefrom, partially absorbed thereinto, and the remaining part penetrates therethrough. An amount of the radio wave being attenuated through the conductor piece varies according to the shape and the size of the conductor piece. In a case where the conductor piece is an end portion open type linear antenna element (dipole) 3 as shown in Fig. 3, the radio wave is partially reflected thereat and also partially absorbed thereinto.

As shown in Fig. 4, a dipole antenna element 3 of a half wavelength ($\lambda/2$) disposed parallelly in a plane electromagnetic field does not receive electromagnetic wave energy only at an area of a metal portion thereof, but absorbs an electromagnetic field at an area of the vicinity of the metal portion thereof. The equivalent sectional area A_e , although the spreading of the electromagnetic field is not uniformed, is calculated by the use of the following equation 1:

[Equation 1]

$$A_e \approx 0.13 \lambda^2 \text{ (area of } \lambda/2 \times \lambda/4 \text{)}$$

About 3/4 of the radio wave radiated to the equivalent sectional area A_e is reflected, and then the remaining about 1/4 is changed to a received electric power. This is called "effective opening".

As shown in Fig. 5, when the above linear antenna of a half wavelength ($\lambda/2$) is set in input resistance to "0" so long as it is an ideal one with no loss, it reflects the electric power into the air, and then the equivalent sectional area becomes four times of the above-mentioned effective opening (scattered opening). Arranging the above-mentioned linear antenna elements 3 on the window glass 1, as shown in Fig. 6, according to the equivalent sectional area $4 \times A_e$ (scattered opening) provides the radio wave reflection effect just as the metal film is laminated thereon. The linear antenna element 3 is basically acted according to the frequency-dependent property, which is generally inherent in the antenna

element, and the receiving end resistance being zero. When the linear antenna has a loss, the radio wave is partially absorbed into the antenna loss resistance as the electric power.

Furthermore, the linear antenna elements 3 are arranged scatteredly, thereby preventing the window glass 1 from being degraded in natural illumination and visibility. Incidentally, the conductor constituting the linear antenna element 3 is selected to be so thin as not to prevent the visibility range and to have a small loss.

Then, the frequency band ranging from 1885 to 1950 MHz is assigned to the existing personal telecommunication (PHS-JAPAN., PCS-US. DECT-Europe) and FPLMTS (Future Public Land Mobile Telephone System) which will be put to practical use on and after A.D. 2000. The frequency band ranging from 2420 to 2480 MHz is assigned to ISM (Industrial-Scientific-Medical)-service, as provided by ITU, which is not only assigned to the radio LAN in the building, but also electronic ovens and large power non destructive inspection-use accelerator.

The radio wave for the PHS has a wavelength λ of about 158 mm when the frequency is 1.90 GHz, and the radio wave for the LAN has a wavelength λ of about 122 mm when the frequency is 2.45 GHz. The linear antenna element 3 serves as an area $4 \times A_e = 12,980 \text{ mm}^2$ for the PHS, and serves as an area $4 \times A_e = 7,740 \text{ mm}^2$ for the LAN, and then the linear antenna elements 3 could be regularly arranged, that is, dot on the surface of the glass or between the

glass plates taking account of the electromagnetic reflection equivalent area $4 \times A_e$.

However, lining the linear antenna elements 3 in the lateral direction as shown in Fig. 6 disables the radio waves of various planes of polarization to be shielded because all the actual radio waves have not laterally-oriented plane of polarization. Therefore, the linear antenna elements 3 are formed of directional end portion open type ones and ring line type ones referred to hereinafter, thereby causing all the radio waves different in plane of polarization from one another to be shielded.

Figs. 1 and 2 show a first embodiment of the invention. A linear antenna element 5 is of an end portion open type reverse Y-like element having one side 5b of a length of about $\lambda/(4\sqrt{\epsilon_q})$, where λ is a wavelength of the electromagnetic wave to be shielded, and ϵ_q is an equivalent relative dielectric constant obtained when the linear antenna elements are arranged on the glass. In other words, the length of the one side 5b of the linear antenna element 5 extending from a center 5a is a $1/4$ wavelength of the radio wave to be shielded, because $\epsilon_q = 1$ holds in the air. However, arranging the linear antenna elements 5 on the glass changes the length of the one side 5b according to the dielectric constants of the glass and the boundary surface.

Moreover, the window glass 1, on which the linear antenna elements 3 or the linear antenna elements 5 are to be disposed, is preferably made of a float method-made

glass, a grey pane glass, or the like. The methods of regularly arranging the linear antenna elements 3 or the linear antenna elements 5 on the surface of the glass or between the glass plates taking account of the electromagnetic field reflection equivalent area of the above antenna element include a metal paste silk printing method and a film laminating method, both of which use silver, copper, gold or the like.

Of the above methods, the film laminating method is capable of preventing the broken glass from being scattered, and of adjusting an amount of sunshine. Further, the film can be laminated additionally after construction, thereby resulting in a relatively low cost of this method. The window glass 1 is produced by arranging a circuit pattern of the linear antenna elements 5 on a film material made of a synthetic resin film such as a polyimide film, a polyester film, and a polyethylene film by the use of an etching method, and a laminating method, or a screen printing method, and then laminating them on the glass, or the like.

The above etching method is composed of the same manner as a method of producing a general printed board by preparing a base board in which a copper foil is laminated on a film as a flexible board, masking a patterned portion of the base board, and melting a remained portion of the masked portion by a solvent. On the contrary, the screen method is to form a circuit pattern by performing a metal paste printing using silver, gold, or the like on the base

board.

There is shown in Fig. 9 an experimental result in which the Y-like linear antenna elements 5 are burning-printed on the surface of the glass by silver-pasting in order to confirm the characteristic of the electromagnetic wave shielding glass on which the Y-like linear antenna elements 5 are arranged.

Fig. 9 shows that a maximum amount of attenuation is 35 dB (mean frequency: 1.9 GHz), and then the attenuation bandwidth at 30 dB as a target is about 35 MHz, thereby bringing about a sufficient shielding characteristic for the band for the PHS radio wave.

The following Table 1 shows particulars of the glass, and Table 2 shows the summary of the experiment.

[Table 1]

Item	Particulars
Plate glass	Grey glass pane 60cm x 60cm Thickness: 8mm
Element	Silver paste burning printing (Ag: 95%, Others: Vitreous material: 5%) Wire length: 21mm Wire width: 0.5mm

[Table 2]

Item	Summary
Measuring method	Insertion loss method by radio wave dark room opening portion (Opening portion size: 110cm x 50cm)
Measuring instrument	Transmitter: Synthesized sweeper Receiver: Spectrum analyzer Antenna: W rigid guide horn antenna
Measuring distance	60cm, 200cm
Incident angle	0°, 60°
Plane of polarization	Vertical/Horizontal polarization

Fig. 10 shows a case in which the linear antenna element 5 is shaped in rectangle, that is, cross. In this case, a center 5a is low in electric potential, and sides 5b each is high in electric potential. In comparison with the case of Fig. 10, according to the case of Fig. 2, a portion of the linear antenna element 5 having a high electric field and a portion of the another linear antenna element 5 having a low electric field are closed to each other, thereby causing the linear antenna elements 5 to be arranged so as to provide continuous triangles, which prevents the portions having the high electric field from being mutually closed to thereby prevent the elements to be

mutually interfered. The arrangement in a triangle manner results in the increase of the density of the elements.

Fig. 12 shows another variant example of the end portion open type linear antenna elements 5. A straight line type one shown at a left side of Fig. 12 has the total length of a $1/2$ wavelength of the radio wave to be shielded.

The experimental result revealed that the window glass 1 on which the linear antenna elements 5 are arranged is capable of shielding the radio waves even if there are no linear antenna elements 5 at the but portion of the glasses (a gap portion between the glasses) on which a packing or the like is arranged. This result shows that the mean frequency of the radio waves is slightly shifted due to the change of the gap distance between the glasses, but that the required shielding characteristic can be satisfied up to about 30 mm of the gap distance.

This experiment is carried out, as shown in Fig. 21, by transmitting the radio waves of a constant output through an antenna in the electromagnetically shielded room having an opening portion (51 cm in width x 111 cm in height), receiving the transmitted radio wave through an antenna outside the electromagnetically shielded room, and measuring the received field intensity by a spectrum analyzer when changing the gap distance between the window glasses 1, comprising two test pieces, according to the invention which are incorporated into opening portions.

As described above, the linear antenna elements 5 are regularly arranged on the window glass 1 taking account

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of an electromagnetic field reflection equivalent area or an electromagnetic field reflection equivalent volume, thereby causing the radio waves to be attenuated. Further, the optimum distance between the linear antenna elements 5 can be determined taking account of a required amount of attenuation.

It is desired that achieving a large amount of attenuation requires to arrange the linear antenna elements 5 so as to be as mutually closed as possible. On the contrary, arranging them on the surface of the window glass so as to be more closed than necessary causes a visual problem (eyesore).

Figs. 23 and 24 show an experimental device for confirming the relationship between the arrangement distance of the linear antenna elements and the amount of attenuation. The experiment is carried out with copper bars considered as the linear antenna elements, which provides the relationship as shown in Fig. 24.

Therefore, the arrangement distance between the linear antenna elements 5 is determined taking account of the relation with amount of attenuation, determining the arrangement distance between the linear antenna elements based on the required amount of attenuation provides a gap between the linear antenna elements in large amounts as much as possible, which provides better visibility on the surface of the glass.

Further, in the above experimental result, the linear antenna element 5, having a line width of 0.5 mm, is

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formed by the silver paste burning-printing; however, it is preferred that the linear antenna element 5 has a volume resistivity of not more than 5×10^{-8} ($\Omega \cdot m$).

To ensure a large amount of attenuation, it is preferred to lower the resistance loss of the linear antenna element as much as possible. For this reason, it is preferred to lower the resistance loss by increasing the wire width, or to use the material having a good conductivity. However, increasing the wire width of the linear antenna element causes the optical transparency of the surface of the glass on which the above linear antenna elements are arranged to be degraded. As described above, according to the invention of claim 11, the linear antenna element has a volume resistivity of 5×10^{-8} ($\Omega \cdot m$) in a case where the linear antenna element has the wire width of about 0.5 mm, thereby resulting in sufficient performance.

Moreover, copper, silver and gold are optimum for the material of the linear antenna element; however, gold is expensive, and copper is increased in resistance due to the oxidation. As described above, introducing silver prevents the cost from being increased and eliminates the possibility for the resistance increasing due to the oxidation, and the mixture of a small amount, e.g. 5% of the vitreous material into the glass permits the vitreous material to be integral with the glass, thereby enabling the service life of the linear antenna element to be elongated to the same degree as the glass.

Figs. 7 and 8 show an example of a ring line type Y-

like linear antenna elements 4 instead of the end portion open type linear antenna elements 5. Further, there is shown in Fig. 11 variant examples of the ring line type linear antenna element 4, which include a triangle type, a rectangular type, other polygonal type, a circle type ones, and the like.

Such a ring line type linear antenna element 4 has a circumferential length (electrical length) being identical with a wavelength of the radio wave to be shielded. More accurately, if λ is a wavelength, and ϵ is an equivalent specific dielectric constant, the linear antenna element 4 is of a ring having a surrounding length of about $\lambda/\sqrt{\epsilon}$.

The ring line type linear antenna element 4 could be thin in line width compared with the end portion open type antenna element 5, and the inductance by a turned-up loop portion of the element 4 is capable of canceling the capacitance component of the element 4, which is shorter than $\lambda/4$ for the end portion open type linear antenna element 5, to achieve a resonant condition. Then, the ring line type linear antenna element 4 raises a low radiation resistance to four times according to the effect of the turned-up portion of the element 4.

The element 4 is short, thereby reducing an electric field intensity to reduce an influence of the dielectric constant to the glass. Increasing a width of the loop portion causes Z_{0b} (characteristic impedance of two parallel lines) to be increased, thereby bringing about an effect of lowering the influence of the glass, and further

causes an equivalent radius to be increased, thereby causing even the thin line to provide a wide band.

There is shown in Fig. 13 another variant embodiment of the end portion open type linear antenna element 5, which is partially shaped in a ring line 5c. This element is of so-called hybrid type one in which the ring line type linear antenna elements are incorporated into the linear antenna element.

There are thus parallelly used many thin lines, thereby increasing a reflection surface area and preventing the transparency from being deteriorated while lowering a high frequency loss resistance value, which results in a high band and a high attenuation.

Incidentally, for example, the portable telephone has two frequency bands of 900 MHz and 1,500 MHz. In a similar manner, the PHS has a frequency of 1.9 GHz, the radio wave LAN has a frequency of 2.45 GHz. Electromagnetically shielding for the above radio wave bands requires to cope with a plurality of frequency bands.

Fig. 14 is a perspective view which is helpful to explain the above-mentioned electromagnetically shielding method which copes with a plurality of frequency bands, according to an embodiment of the invention, in which a plurality of linear antenna elements different in length from one another are combined then regularly arranged. In this embodiment, combinations of the ring line type linear antenna element 4 and the end portion open type linear antenna element 5 are regularly arranged taking account of

the equivalent electromagnetic field reflection area and the equivalent electromagnetic field reflection volume, respectively, and further the end portion open type linear antenna element 5 is shaped in Y, and the ring line antenna element 4 is shaped is regular triangle, as shown in Fig. 15. Moreover, the linear antenna element 3 is of double type; however, this may be of single type one.

Besides, the linear antenna element 5 is disconnectively received in the linear antenna element 4, thereby reducing an interference between the elements. Fig. 16 shows an electromagnetic shielding effect of the linear antenna elements 4, 5 shown in Fig. 15, in which the axis of ordinates represents an amount of attenuation, and the axis of abscissas represents a frequency. (In Fig. 16, DDS represents a case in which the linear antenna element 3 is of double type, and SDS represents a case in which it is single type.)

There is shown in Fig. 17 a variant embodiment of combinations of the ring line type linear antenna element 4 and the end portion open type linear antenna element 5. In Fig. 17, reference symbol a designates an example in which the end portion is folded.

Furthermore, an electromagnetic shielding method which copes with a plurality of frequency bands can be applied to a case in which the end portion open type linear antenna elements 5 different in length from one another are combined as shown in Fig. 18, or a case in which the ring line type linear antenna elements 4 different in length

from one another are combined as shown in Fig. 19.

There is shown in Fig. 20 an examples of the combination of linear antenna elements which copes with a plurality of frequency bands, e.g. three frequency bands.

Moreover, the above description is directed to the above embodiments applied to the window glass for use in the windows of the building; however, they can be applied to the window glasses of vehicles such as automobiles and trains, and the window glasses of furniture and fixtures such as partitions and boxes.

Industrial Availability

As described above, the window glass according to the invention is capable of electromagnetically shielding only the radio wave having the frequency band corresponding to the length of the antenna element, but causing the other radio wave to pass therethrough, which causes only the radio wave having the required frequency band to be selected then realize an electromagnetic shielding.

Further, the above window glass is capable of realize an electromagnetic shielding of at a maximum of about 40 dB, and providing a reflection region around the antenna elements, thereby providing the electromagnetic shielding characteristic even if some gap is in existence, and enabling the antenna element to be thinned, with no degradation of the natural illumination and the visibility.

Besides, there is no need to treat the gap portion between the above members and to electrically connect them for the purpose of earthing by the electrically connecting

member.



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What is claimed is:

1. A window glass having an electromagnetic shielding characteristic, wherein linear antenna elements each having such a length as to cause a radio wave, which is to be shielded, to be resonated are arranged on a surface of a glass or between glass plates taking account of an electromagnetic field reflection equivalent area (scattering opening area) or an electromagnetic field reflection equivalent volume (scattering opening volume), said linear antenna element causing said radio wave to be scattered to thereby be attenuated.
2. A window glass having an electromagnetic shielding characteristic, as claimed in claim 1, wherein said linear antenna element (5) is of an end portion open type, of which one side (5b), extending from a center thereof, having a length (electrical length) which is identical with the $1/4$ wavelength ($1/2$ wavelength in the case of a straight type one) of the radio wave to be shielded.
3. A window glass having an electromagnetic shielding characteristic, as claimed in claim 1, wherein said linear antenna element (4) is of a ring line type, of which surrounding length (electrical length) is identical with the wavelength of said radio wave to be shielded.
4. A window glass having an electromagnetic shielding characteristic, as claimed in any one of claims 1 to 3, wherein said linear antenna element is composed of a plurality of kinds of linear antenna elements for shielding a plurality of frequencies, in which two or more kinds of

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linear antenna elements different in size and shape from one another are arranged so as to be combined.

5. A window glass having an electromagnetic shielding characteristic, as claimed in claim 4, wherein said linear antenna element is composed of a plurality of kinds of linear antenna elements for shielding a plurality of frequencies, in which an end portion open type linear antenna element (5) and a ring line type linear antenna element (4).

6. A window glass having an electromagnetic shielding characteristic, as claimed in claim 4, wherein said linear antenna element is composed of a plurality of kinds of linear antenna elements for shielding a plurality of frequencies, in which end portion open type linear antenna elements (5) different in length from one another are combined.

7. A window glass having an electromagnetic shielding characteristic, as claimed in claim 4, wherein said linear antenna element is composed of a plurality of kinds of linear antenna elements for shielding a plurality of frequencies, in which ring line type linear antenna elements (4) different in length from one another are combined.

8. A window glass having an electromagnetic shielding characteristic, as claimed in claim 2, wherein said end portion open type linear antenna elements (5) are arranged in such a manner that respective side ends of one of said linear antenna elements (5) is closed to centers (5a) of

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the others of said linear antenna elements (5) adjacent to said one of said linear antenna elements (5).

9. A window glass having an electromagnetic shielding characteristic, as claimed in claim 2, wherein said end portion open type linear antenna elements (5) is partially of a ring line type.

10. A window glass having an electromagnetic shielding characteristic, as claimed in any one of claims 1 to 9, wherein arrangement distances between said linear antenna elements are determined taking account of the relationship with an amount of attenuation.

11. A window glass having an electromagnetic shielding characteristic, as claimed in any one of claims 1 to 10, wherein said linear antenna element has a volume resistivity of not more than 5×10^{-8} ($\Omega \cdot m$).

12. A window glass having an electromagnetic shielding characteristic, as claimed in any one of claims 1 to 11, wherein said linear antenna element is made of a material which is superior in conductivity, durability, and weather-resistant, and contains a small amount of vitreous material.

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