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(54) **RECEPTION AND RE-TRANSMISSION OF ELECTROMAGNETIC RADIATION**

(57) Reception and re-transmission of electromagnetic radiation.

An optically translucent passive electromagnetic resonator for anisotropic direction of electromagnetic radiation comprising:

a ground plane;

a reception conductor configured to receive from an exterior, electromagnetic radiation within one or more bandwidths; and

a transmission conductor configured to transmit to an interior 52 electromagnetic radiation within the one or more bandwidths;

wherein the ground plane is optically translucent, the reception conductor is optically translucent and the transmission conductor is optically translucent;

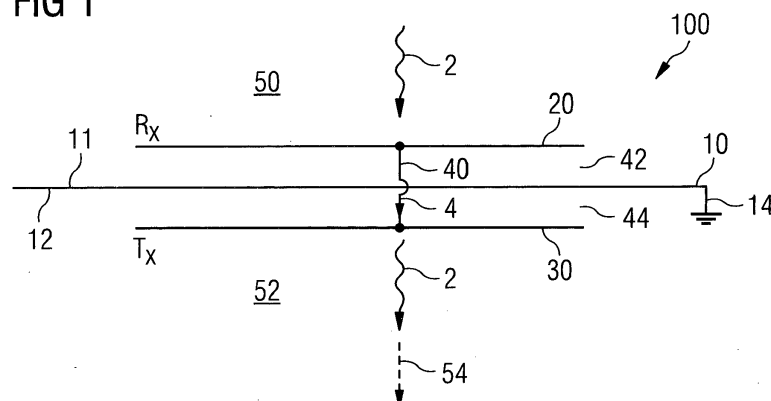
wherein the reception conductor, for facing the exterior, is physically separated from a first side of the ground

plane by a first dielectric and is coupled 40 to the transmission conductor to transfer electromagnetic energy within the one or more bandwidths preferentially to the transmission conductor;

wherein the transmission conductor, for facing the interior 52, is physically separated from a second side of the ground plane by a second dielectric and is coupled 40 to the reception conductor to receive electromagnetic energy within the one or more bandwidths preferentially from the reception conductor;

and wherein the ground plane, the reception conductor and the transmission conductor are configured to cause the reception conductor to receive electromagnetic radiation within the one or more bandwidths preferentially from the exterior and to cause the transmission conductor to transmit electromagnetic radiation within the one or more bandwidths preferentially to the interior 52.

FIG 1



Description

TECHNOLOGICAL FIELD

[0001] Embodiments of the present invention relate to reception and re-transmission of electromagnetic radiation.

BACKGROUND

[0002] A radio repeater usually consists of a powered radio receiver connected to a powered radio transmitter. The received signal is amplified and retransmitted to provide additional coverage. A duplexer can allow the repeater to use one antenna for both receiver and transmitter.

[0003] A cellular repeater is a powered bi-directional amplifier. A typical indoor cellular repeater system consists of an exterior antenna that receives from and transmits to an exterior base station, a powered radio frequency (RF) signal amplifier, cabling, and an indoor rebroadcast antenna that receives from and transmits to an interior of a building.

[0004] These solutions are relatively expensive because they involve reception, bandpass filtering, power amplification, current/power consumption and re-transmission and are typically only deployed to enable communication with multiple users within large buildings.

[0005] It would be desirable to provide an alternative solution.

BRIEF SUMMARY

[0006] According to various, but not necessarily all, embodiments of the invention there is provided an optically translucent passive electromagnetic resonator for anisotropic direction of electromagnetic radiation comprising:

- a ground plane;
- a reception conductor configured to receive from an exterior electromagnetic radiation within one or more bandwidths; and
- a transmission conductor configured to transmit to an interior, electromagnetic radiation within the one or more bandwidths;
- wherein the ground plane is optically translucent, the reception conductor is optically translucent and the transmission conductor is optically translucent;
- wherein the reception conductor, for facing the exterior, is physically separated from a first side of the ground plane by a first dielectric and is coupled to the transmission conductor to transfer electromagnetic energy within the one or more bandwidths preferentially to the transmission conductor;
- wherein the transmission conductor, for facing the interior, is physically separated from a second side of the ground plane by a second dielectric and is

coupled to the reception conductor to receive electromagnetic energy within the one or more bandwidths preferentially from the reception conductor; and wherein the ground plane, the reception conductor and the transmission conductor are configured to cause the reception conductor to receive electromagnetic radiation within the one or more bandwidths preferentially from the exterior and to cause the transmission conductor to transmit electromagnetic radiation within the one or more bandwidths preferentially to the interior.

[0007] According to various, but not necessarily all, embodiments of the invention there is provided a method of providing an optically translucent passive electromagnetic resonator for anisotropic direction of electromagnetic radiation comprising:

- providing an optically translucent ground plane;
- providing a an optically translucent reception conductor that is configured to receive electromagnetic radiation within one or more bandwidths preferentially from an exterior;
- providing an optically translucent transmission conductor that is configured to transmit electromagnetic radiation within the one or more bandwidths preferentially to an interior;
- coupling the optically translucent reception conductor to the optically-translucent transmission conductor to enable transfer of electromagnetic energy within one or more bandwidths from the optically translucent reception conductor to the optically-translucent transmission conductor.

[0008] According to various, but not necessarily all, embodiments of the invention there is provided examples as claimed in the appended claims.

BRIEF DESCRIPTION

[0009] For a better understanding of various examples that are useful for understanding the detailed description, reference will now be made by way of example only to the accompanying drawings in which:

- Fig 1 illustrates an example of an optically translucent passive electromagnetic resonator for anisotropic direction of electromagnetic radiation;
- Fig 2 illustrates an example of a plot of return loss;
- Fig 3A schematically illustrates an example of a radiation pattern (far-field pattern) of a reception conductor of a first example optically translucent passive electromagnetic resonator and Fig 3B schematically illustrates an example of a radiation pattern (far-field pattern) of a transmission conductor of the first example optically translucent passive electromagnetic resonator;
- Fig 3C schematically illustrates an example of a ra-

diation pattern (far-field pattern) of a reception conductor of a second example optically translucent passive electromagnetic resonator and Fig 3D schematically illustrates an example of a radiation pattern (far-field pattern) of a transmission conductor of the second example optically translucent passive electromagnetic resonator;

Figs 4A-4D illustrates examples of one or more planar conductive elements of the reception conductor and/or the transmission conductor;

Fig 5 illustrates the translucent passive electromagnetic resonator as a stacked structure comprising multiple layers;

Fig 6 illustrates an example of the translucent passive electromagnetic resonator as an adhesive window film;

Figs 7A to 7D illustrate examples of a construction unit comprising the translucent passive electromagnetic resonator;

Fig 8 illustrates a translucent passive electromagnetic resonator forming part of a larger construction;

Fig 9 illustrates an example of a method of providing an optically translucent passive electromagnetic resonator for anisotropic direction of electromagnetic radiation.

DETAILED DESCRIPTION

[0010] This description enables a new solution for improving, inter alia, reception inside a building and it is particularly useful for home use. The solution uses a passive resonator to provide passive (unpowered) amplification. The passive amplification is only available close to the resonator. Spatial anisotropy between radiation patterns of a reception conductor and a transmission conductor provide directivity gain (passive amplification).

[0011] Fig 1 illustrates an example of an apparatus 100. The apparatus 100 is an optically translucent passive electromagnetic resonator 100 for anisotropic direction of electromagnetic radiation 2.

[0012] The optically translucent passive electromagnetic resonator 100 comprises:

a ground plane 10; a reception conductor 20 and a transmission conductor 30. The term optically translucent means that visible light can pass through.

[0013] The ground plane 10 is optically translucent, the reception conductor 20 is optically translucent and the transmission conductor 30 is optically translucent.

[0014] A translucent component of the resonator 100 is a component that is not opaque and allows the passage of visible light with or without scattering. In some but not necessarily all examples, the translucent components are additionally transparent components that allow the passage of visible light without scattering or without significant scattering.

[0015] Where the resonator 100 or any component of

the resonator 100 is described as translucent, it should be appreciated that the resonator 100 and the component(s) may additionally be transparent.

[0016] The reception conductor 20 is physically separated from a first side 11 of the ground plane 10 by a first dielectric 42. The reception conductor 20, in use, faces an exterior 50 from which electromagnetic radiation 2 is received.

[0017] In some but not necessarily all examples, the reception conductor 20 is electrically insulated from the ground plane 10. In other examples, the reception conductor 20 is electrically interconnected to the ground plane 10 and the ground plane 10 forms a resonator.

[0018] The transmission conductor 30 is physically separated from a second side 12 of the ground plane 10 by a second dielectric 44. The transmission conductor 30 in use faces an interior 52 to which electromagnetic radiation 2 is transmitted.

[0019] In some but not necessarily all examples, the transmission conductor 30 is electrically insulated from the ground plane 10. In other examples, the reception conductor 20 is electrically interconnected to the ground plane 10 and the ground plane 10 forms a resonator.

[0020] The first side 11 of the ground plane 10 and the second side 12 of the ground plane 10 are opposite sides of the ground plane 10. The first side 11, in use, faces towards the exterior 50 and the second side 12, in use, faces towards the interior 52.

[0021] The exterior 50 and the interior 52 are, in use, on opposite sides of the resonator 100.

[0022] The ground plane 10, the reception conductor 20 and the transmission conductor 30 are configured to cause the reception conductor 20 to receive electromagnetic radiation 2 within one or more bandwidths 60 preferentially from the exterior 50 and to cause the transmission conductor 30 to transmit electromagnetic radiation 2 within the one or more bandwidths 60 preferentially to the interior 52.

[0023] The reception conductor 20 is configured to receive from an exterior 50 electromagnetic radiation 2 within the one or more bandwidths 60. The reception conductor 20 is coupled by coupling 40 to the transmission conductor 30 to transfer electromagnetic energy 4 within the one or more bandwidths 60 preferentially to the transmission conductor 30.

[0024] The transmission conductor 30 is coupled by a coupling 40 to the reception conductor 20 to receive electromagnetic energy 4 within the one or more bandwidths 60 preferentially from the reception conductor 20. The transmission conductor 30 is configured to transmit to an interior 52 electromagnetic radiation 2 within the one or more bandwidths 60.

[0025] The coupling 40 may be a galvanic (direct current) coupling such as an interconnecting conductor. The coupling 40 may be a reactive (alternating current) coupling such as an aperture coupling.

[0026] The term 'bandwidth' refers to an 'operational bandwidth'. An operational bandwidth (operational res-

onant mode) is a continuous frequency range over which an antenna radiator can efficiently operate. An operational bandwidth may be a receive only band or a transmit only band (a sub-band) or a receive and transmit band (a complete band). An operational bandwidth (operational resonant mode) may be defined as where the return loss S11 (reflection coefficient) is less than an operational threshold T such as, for example, -3 or -4 dB.

[0027] Fig 2 illustrates an example of a plot 62 of return loss S11 (reflection coefficient), the level 64 of the threshold T and the defined bandwidth 60 which is centered on the center frequency 61.

[0028] The optically translucent passive electromagnetic resonator 100 may be configured to operate in one or more operational resonant frequency bands or sub-bands. For example, the operational frequency bands may include (but are not limited to) Long Term Evolution (LTE) (US) (734 to 746 MHz and 869 to 894 MHz), Long Term Evolution (LTE) (rest of the world) (791 to 821 MHz and 925 to 960 MHz), amplitude modulation (AM) radio (0.535-1.705 MHz); frequency modulation (FM) radio (76-108 MHz); Bluetooth (2400-2483.5 MHz); wireless local area network (WLAN) (2400-2483.5 MHz); hiper local area network (HiperLAN) (5150-5850 MHz); global positioning system (GPS) (1570.42-1580.42 MHz); US - Global system for mobile communications (US-GSM) 850 (824-894 MHz) and 1900 (1850 - 1990 MHz); European global system for mobile communications (EGSM) 900 (880-960 MHz) and 1800 (1710 - 1880 MHz); European wideband code division multiple access (EU-WCDMA) 900 (880-960 MHz); personal communications network (PCN/DCS) 1800 (1710-1880 MHz); US wideband code division multiple access (US-WCDMA) 1700 (transmit: 1710 to 1755 MHz, receive: 2110 to 2155 MHz) and 1900 (1850-1990 MHz); wideband code division multiple access (WCDMA) 2100 (transmit: 1920-1980 MHz, receive: 2110-2180 MHz); personal communications service (PCS) 1900 (1850-1990 MHz); time division synchronous code division multiple access (TD-SCDMA) (1900 MHz to 1920 MHz, 2010 MHz to 2025 MHz), ultra wideband (UWB) Lower (3100-4900 MHz); UWB Upper (6000-10600 MHz); digital video broadcasting - handheld (DVB-H) (470-702 MHz); DVB-H US (1670-1675 MHz); digital radio mondiale (DRM) (0.15-30 MHz); worldwide interoperability for microwave access (WiMax) (2300-2400 MHz, 2305-2360 MHz, 2496-2690 MHz, 3300-3400 MHz, 3400-3800 MHz, 5250-5875 MHz); digital audio broadcasting (DAB) (174.928-239.2 MHz, 1452.96- 1490.62 MHz); radio frequency identification low frequency (RFID LF) (0.125-0.134 MHz); radio frequency identification high frequency (RFID HF) (13.56-13.56 MHz); radio frequency identification ultra high frequency (RFID UHF) (433 MHz, 865-956 MHz, 2450 MHz).

[0029] The operational frequency bands may for example also extend to future operational frequency bands when they are defined such as, for example, 5G operational frequency bands.

[0030] Figs 3A and 3B schematically illustrate plots of radiation patterns of the reception conductor 20 and the transmission conductor 30 for a first example of the optically translucent passive electromagnetic resonator 100.

[0031] Fig 3A schematically illustrates an example of a plot of a radiation pattern (far-field pattern) of the reception conductor 20. The radiation pattern is a directional (angular) pattern.

[0032] The reception conductor 20 has a partly isotropic radiation pattern 70 in that it is capable of receiving with efficiency above a first threshold X, electromagnetic radiation within the one or more bandwidths 60 from any direction (all directions) in the exterior 50. In this example, however, it is also partly anisotropic and does not receive with the same efficiency from all directions in the exterior 50.

[0033] Fig 3B schematically illustrates an example of a plot of a radiation pattern (far-field pattern) of the transmission conductor 30. The radiation pattern is a directional (angular) pattern orientated similarly to Fig 3A..

[0034] The transmission conductor 30 has an anisotropic radiation pattern 70 that concentrates transmitted electromagnetic radiation 2 in a particular interior direction 54.

[0035] The ground plane 10, the reception conductor 20 and the transmission conductor 30 are configured to cause the reception conductor 20 to receive electromagnetic radiation 2 within one or more bandwidths 60 from a majority of exterior directions and to cause the transmission conductor 30 to transmit electromagnetic radiation 2 within the one or more bandwidths 60 preferentially towards a particular interior direction 54. This provides for directivity gain along the particular interior direction 54.

[0036] There is signal gain within 1/2 or 1 m of the transmission conductor 30 in the particular direction 54 compared to an absence of the optically translucent passive electromagnetic resonator 100.

[0037] Referring back to Fig 1, in this first example, the transmission conductor 30 lies in a flat plane and the particular direction 54 is normal (orthogonal) to the plane. In this first example, the reception conductor 20 and the transmission conductor 30 are symmetric. The reception conductor has the same number and arrangement of planar conductive elements as the transmission conductor. The one or more planar conductive elements of the reception conductor 20 are paired with the one or more planar conductive elements of the transmission conductor 30. This requires the number of planar conductive elements of the reception conductor 20 to equal the number of planar conductive elements of the transmission conductor 30. The paired planar conductive elements have the same size and shape.

[0038] Figs 3C and 3D schematically illustrate plots of radiation patterns of the reception conductor 20 and the transmission conductor 30 for a second example of the optically translucent passive electromagnetic resonator

100.

[0039] Fig 3C schematically illustrates an example of a plot of a radiation pattern (far-field pattern) of the reception conductor 20. The radiation pattern is a directional (angular) pattern. The reception conductor 20 has an anisotropic radiation pattern 70 and does not receive with the same efficiency from all directions in the exterior 50.

[0040] Fig 3D schematically illustrates an example of a plot of a radiation pattern (far-field pattern) of the transmission conductor 30. The radiation pattern is a directional (angular) pattern orientated similarly to Fig 3C. The transmission conductor 30 has an anisotropic radiation pattern 70 that concentrates transmitted electromagnetic radiation 2 in a particular interior direction 54 with increased directional gain.

[0041] The ground plane 10, the reception conductor 20 and the transmission conductor 30 are configured to cause the reception conductor 20 to receive electromagnetic radiation 2 within one or more bandwidths 60 from exterior directions and to cause the transmission conductor 30 to transmit electromagnetic radiation 2 within the one or more bandwidths 60 preferentially towards a particular interior direction 54 with increased gain.

[0042] There is signal gain within 1/2 or 1 m of the transmission conductor 30 in the particular direction 54 compared to an absence of the optically translucent passive electromagnetic resonator 100.

[0043] Referring back to Fig 1, in this second example, the transmission conductor 30 lies in a flat plane and the particular direction 54 is normal (orthogonal) to the plane. In this second example, the reception conductor 20 and the transmission conductor 30 are non-symmetric. The reception conductor 20 has a different number and arrangement of planar conductive elements as the transmission conductor 30. The transmission conductor 30 has more planar conductive elements than the reception conductor 20. The planar conductive elements may have the same size and shape.

[0044] The translucent passive electromagnetic resonator 100 is configured to operate without power input circuitry, power harvesting circuitry, power storage circuitry or power distribution circuitry, other than the reception conductor 20, the transmission conductor 30 and any coupling 40 between the reception conductor 20, and the transmission conductor 30.

[0045] The ground plane 10 may be a continuous planar conductive layer with a ground (earth) connector 14 which may be external to the optically translucent passive electromagnetic resonator 100.

[0046] The translucent passive electromagnetic resonator 100 in the illustrated example, comprises one or more couplings 40 between the reception conductor 20 and the transmission conductor 30. Each coupling 40 may be a galvanic interconnection between the reception conductor 20 and the transmission conductor 30.

[0047] The reception conductor 20 and/or the transmission conductor 30 may comprise one or more planar

conductive elements 80 as illustrated in Fig 4A-4D.

[0048] Fig 4A illustrates a single planar conductive element 80. In this example it is a square of side length L. However, in other examples it may have a different shape, for example and not limited to, a rectangle, a circle, an oval, a triangle, an irregular multi-sided shape, or any combination of the above shapes.

[0049] Figs 4B, 4C, 4D illustrate multiple planar conductive elements 80. In this example each planar conductive element is a square of side length L. However, in other examples it may have a different shape. The planar conductive elements are arranged in a N column x M row array. In Fig 4B the array is a 1xM array. In Fig 4C the array is a Nx1 array. In Fig 4D the array is a NxM array.

[0050] In some but not necessarily all examples, the one or more planar conductive elements 80 of the reception conductor 20 are paired with the one or more planar conductive elements 80 of the transmission conductor 30. This requires the number of planar conductive elements 80 of the reception conductor 20 to equal the number of planar conductive elements 80 of the transmission conductor 30. In other examples, the transmission conductor 30 has more planar conductive elements 80 than the reception conductor 20 to increase gain and directivity.

[0051] Each planar conductive element 80 of the transmission conductor 30 is interconnected via one or more couplings 40 (e.g. galvanic interconnections) to the one planar conductive element 80 of the reception conductor 20 and vice versa.

[0052] In some but not necessarily all examples, the one or more planar conductive elements 80 of the reception conductor 20 are aligned with the one or more planar conductive elements 80 of the transmission conductor 30. This requires the number, size and orientation of planar conductive elements 80 of the reception conductor 20 to equal the number, size and orientation of planar conductive elements 80 of the transmission conductor 30. It also requires that each planar conductive element 80 of the reception conductor 20 directly overlies a conductive element 80 of the transmission conductor 30 so that the perimeters of paired planar conductive elements 80 of the respective conductors 20, 30 are aligned.

[0053] The physical dimensions of the one or more planar conductive elements 80 may be matched to the resonant modes of the translucent passive electromagnetic resonator 100. The resonant modes of the translucent passive electromagnetic resonator 100 define the one or more bandwidths 60.

[0054] Thus each of the one or more planar conductors 80 is a resonator. The reception conductor 20 comprises one or more resonators and the transmission conductor 30 comprises one or more resonators.

[0055] In this example, each planar conductive element 80 is a patch and has a physical dimension e.g. length or width that provides an equivalent electrical length that is a half wavelength ($\lambda/2$) of the central fre-

quencies 61 of the one or more bandwidths 60.

[0056] The electrical length may be engineered by adding capacitance and/or inductance. This may be achieved, for example, by adding additional conductive elements that capacitively couple to the planar conductive element(s) 80 and/or by adding slots to the planar conductive element(s) 80.

[0057] The one or more couplings 40 between the reception conductor 20 and the transmission conductor 30 may be used to control polarized reception of the translucent passive electromagnetic resonator 100. For example, linear, circular or elliptical polarization may be controlled by controlling the number/positions of couplings 40 to each planar conductive element 80 of the reception conductor 20.

[0058] The transmission conductor 30 may comprise one or more planar conductive elements 80. The physical dimensions of the one or more planar conductive elements 80 may be matched to the resonant modes of the translucent passive electromagnetic resonator 100.

[0059] The one or more couplings 40 between the reception conductor 20 and the transmission conductor 30 may be used to control polarized transmission of the translucent passive electromagnetic resonator 100. For example, linear, circular or elliptical polarization may be controlled by controlling the number/positions of couplings 40 to each planar conductive element 80 of the transmission conductor 30.

[0060] The reception conductor 20 (and its one or more planar conductive elements 80) and the transmission conductor 30 (and its one or more planar conductive elements 80) may be formed from optically translucent/transparent electrically conductive material, for example, indium tin oxide, graphene, silver nanowires, carbon nanotubes etc.

[0061] The first dielectric 42 and the second dielectric 44 may be formed for optically translucent/transparent dielectric material, for example, glass, plastics such as polydimethylsiloxane (PDMS), polyurethane, and cellophane.

[0062] The translucent passive electromagnetic resonator 100 may be a stacked structure 90 comprising multiple layers 92 as illustrated in Fig 5. Each layer 92 is translucent/transparent.

[0063] In some but not necessarily all examples the translucent passive electromagnetic resonator 100 is flexible and each of the multiple layers 92 is flexible.

[0064] In the particular example illustrated in Fig 5, the reception conductor 20 (and its one or more planar conductive elements 80) lie in a first flat plane 94, the transmission conductor 30 (and its one or more planar conductive elements 80) lie in a different second flat plane 96 that is parallel to the first flat plane 94, and the ground plane 10 is in a different intermediate flat plane 98 between and parallel to the first flat plane 94 and the second flat plane 96. The particular direction 54 is normal (orthogonal) to the flat planes.

[0065] The first dielectric 42 may also lie in a further

parallel flat plane between the first flat plane 94 and the intermediate flat plane 98. The second dielectric 44 may also lie in a further parallel flat plane between the second flat plane 96 and the intermediate flat plane 98.

[0066] In this example, the stacked structure 90 additionally comprises a translucent (or transparent) exterior-facing protective substrate 84 adjacent and protecting the reception conductor 20 and a translucent interior-facing protective substrate 86 adjacent and protecting the transmission conductor 30.

[0067] The first dielectric 42 is a translucent dielectric substrate, between the reception conductor 20 and ground plane 10. The second dielectric 44 is a translucent dielectric substrate, between the transmission conductor 30 and ground plane 10.

[0068] Fig 6 illustrates an example of the stacked structure 90 of Fig 5 configured as an adhesive window film 110. The components of the stacked structure 90 may be translucent or transparent. In some but not necessarily all examples, the components of the stacked structure 90 may be flexible providing a flexible adhesive window film 110.

[0069] The adhesive window film 110 comprises a translucent (or transparent) exterior-facing protective substrate 84 protecting the reception conductor 20 and a translucent (or transparent) interior-facing protective substrate 86 protecting the transmission conductor 30. The first dielectric 42 is a translucent (or transparent) dielectric substrate, between the reception conductor 20 and ground plane 10. The second dielectric 44 is a translucent (or transparent) dielectric substrate, between the transmission conductor 30 and ground plane 10.

[0070] There are one or more couplings 40 (e.g. galvanic interconnections) between the reception conductor 20 and the transmission conductor 30.

[0071] Either the exterior-facing protective substrate 84 or the interior-facing protective substrate 86 comprises an adhesive layer 88. In this example, the exterior-facing protective substrate 84 comprises the adhesive layer 88 enabling the adhesive window film to be adhesively attached to an interior-facing surface of a window.

[0072] In some but not necessarily all examples, in the adhesive window film 110, the translucent exterior-facing protective substrate 84, the translucent interior-facing protective substrate 86 or an additional substrate may provide a filter for filtering incident light and providing shade or reduction in light transmission.

[0073] Figs 7A to 7D illustrate examples of a construction unit 120 comprising the translucent passive electromagnetic resonator 100.

[0074] As illustrated in Fig 8, the translucent passive electromagnetic resonator 100, whether or not it is part of a construction unit 120, can form part of a larger construction 200. The construction unit 120 may be, for example, a window unit (as illustrated). The larger construction 200 may, for example, and not limited to, be a building such as a house (as illustrated) or any other building for example a bus shelter, office, public building or may, for

example, be a vehicle such as a train, automobile, etc. In this illustrated example, the construction unit 120 comprising the translucent passive electromagnetic resonator 100 is integrated into the fabric of a building that separates the exterior (of the building) 50 from the interior (of the building) 52.

[0075] Referring back to Figs 7A to 7D, the construction unit 120 in these examples is a pre-formed construction unit for placement within a larger construction 200 (e.g. a building structure) to improve electromagnetic radiation reception within an interior 52 of the larger construction 200.

[0076] The construction unit 120 comprises a frame 122 providing multiple fluid-separated window glass panels 124 including at least a first window glass panel 124₁ and a second different window glass panel 124₂.

[0077] In these examples, the construction unit 120 forms a stacked structure 90 as illustrated in Fig 5 except that some parts of the construction unit 120 provide layers of the stacked structure 90 or layers that separate the layers of the stacked structure 90. So long as the order of the resonator 100 components -reception conductor 20, first dielectric 42, ground plane 10, second dielectric 44, transmission conductor 30 is maintained, different combinations of the components can be supported on different surfaces of the same window glass panels 124 or by different window glass panels 124. In some examples, the first dielectric 42 may be a window glass panel 124 and/or the second dielectric 44 may be a window glass panel 124.

In some examples, the exterior-facing protective substrate 84 may be a window glass panel 124 and/or the interior-facing protective substrate 86 may be a window glass panel 124.

[0078] In the particular examples illustrated, the first window glass panel 124₁ supports the reception conductor 20 on either an interior-facing surface or an exterior-facing surface and the second window glass panel 124₂ supports the transmission conductor 30 on either an interior-facing surface or an exterior-facing surface. It should be noted that an exterior-facing surface, a surface facing the exterior 50, may be an internal component of the construction unit 120. It should be noted that an interior-facing surface, a surface facing the interior 52, may be an external component of the construction unit 120. There is at least one fluid gap 126 between the reception conductor 20 and the transmission conductor 30.

[0079] The couplings 40 (e.g. galvanic interconnection(s)) between the reception conductor 20 and the transmission conductor 30 are routed via the frame 122 but are electrically insulated from the frame 122. The ground plane 10 in these examples is galvanically interconnected to the window frame 122, which is made of electrically conductive material. It may, for example, be metallic.

[0080] Referring to Fig 7A, a first window glass panel 124₁ can support the reception conductor 20 on its interior-facing surface (not illustrated) or on its exterior-facing

surface (as illustrated), for example covered by a protective layer, and supports the ground plane 10 of its interior-facing surface. The ground plane 10 and the reception conductor 20 are electrically insulated from each other by the first dielectric 42, which may be provided by the first window glass panel 124₁ (as illustrated) or by an additional layer on the interior-facing surface of the first window glass panel 124₁ between the reception conductor 20 and the ground plane 10 (not illustrated).

[0081] There is at least one fluid gap 126 between the ground plane 10 and the transmission conductor 30 which may be on an interior-facing surface of the second window glass panel 124₂ (illustrated) or on an exterior-facing surface of the second window glass panel 124₂ (not illustrated), covered by a protective layer. In the illustrated example, the transmission conductor 30 is on an interior-facing surface of the second window glass panel 124₂.

[0082] Referring to Fig 7B, a second window glass panel 124₂ supports the transmission conductor 30 on its interior-facing surface (not illustrated) or on its exterior-facing surface (illustrated), covered by a protective layer, and supports the ground plane 10 of its interior-facing surface. The ground plane 10 and the transmission conductor 30 are electrically insulated from each other by the second dielectric 44, which may be provided by the second window glass panel 124₂ (as illustrated) or by an additional layer on the interior-facing surface of the second window glass panel 124₂ between the transmission conductor 30 and the ground plane 10 (not illustrated).

[0083] There is at least one fluid gap 126 between the ground plane 10 and the reception conductor 20 which may be on an interior-facing surface of the first window glass panel 124₁ (not illustrated) or on an exterior-facing surface of the first window glass panel 124₁ (illustrated), covered by a protective layer. In the illustrated example, the reception conductor 20 is on an interior-facing surface of the first window glass panel 124₁.

[0084] Referring to Figs 7C and 7D, an intermediate window glass panel 124₃ between the first window glass panel 124₁ and the second window glass panel 124₂ supports the ground plane 10. In the particular examples illustrated, the second window glass panel 124₂ supports the transmission conductor 30 on its interior-facing surface and the first window glass panel 124₁ supports the reception conductor 20 on its interior-facing surface. There is at least one fluid gap 126 between the ground plane 10 and the reception conductor 20 and at least one different fluid gap 126 between the ground plane 10 and the transmission conductor 30. In Fig 7C, the intermediate window glass panel 124₃ supports the ground plane 10 on an exterior-facing surface. In Fig 7D, the intermediate window glass panel 124₃ supports the ground plane 10 on an interior-facing surface.

[0085] The fluid gaps 126 may be filled with gas such as air or argon, for example.

[0086] Fig 9 illustrates an example of a method 300 of

providing an optically translucent passive electromagnetic resonator 100 for anisotropic direction of electromagnetic radiation 2 comprising:

at block 302, providing an optically translucent ground plane 10;
 at block 304, providing an optically translucent reception conductor 20 that is configured to receive electromagnetic radiation 2 within one or more bandwidths 60 preferentially from an exterior 50;
 at block 306, providing an optically translucent transmission conductor 30 that is configured to transmit electromagnetic radiation 2 within the one or more bandwidths 60 preferentially to an interior 52;
 and at block 308, coupling the optically translucent reception conductor 20 to the optically-translucent transmission conductor 30 to enable transfer of electromagnetic energy 4 within one or more bandwidths 60 from the optically translucent reception conductor 20 to the optically-translucent transmission conductor 30.

[0087] In some but not necessarily all examples, the optically translucent reception conductor 20 is electrically insulated from the ground plane 10 and/or the an optically translucent transmission conductor 30 is electrically insulated from the ground plane 10.

[0088] Where a structural feature has been described, it may be replaced by means for performing one or more of the functions of the structural feature whether that function or those functions are explicitly or implicitly described.

[0089] The term 'comprise' is used in this document with an inclusive not an exclusive meaning. That is any reference to X comprising Y indicates that X may comprise only one Y or may comprise more than one Y. If it is intended to use 'comprise' with an exclusive meaning then it will be made clear in the context by referring to "comprising only one" or by using "consisting".

[0090] In this brief description, reference has been made to various examples. The description of features or functions in relation to an example indicates that those features or functions are present in that example. The use of the term 'example' or 'for example' or 'may' in the text denotes, whether explicitly stated or not, that such features or functions are present in at least the described example, whether described as an example or not, and that they can be, but are not necessarily, present in some of or all other examples. Thus 'example', 'for example' or 'may' refers to a particular instance in a class of examples. A property of the instance can be a property of only that instance or a property of the class or a property of a sub-class of the class that includes some but not all of the instances in the class. It is therefore implicitly disclosed that a feature described with reference to one example but not with reference to another example, can where possible be used in that other example but does not necessarily have to be used in that other example.

[0091] Although embodiments of the present invention have been described in the preceding paragraphs with reference to various examples, it should be appreciated that modifications to the examples given can be made without departing from the scope of the invention as claimed.

[0092] Features described in the preceding description may be used in combinations other than the combinations explicitly described.

[0093] Although functions have been described with reference to certain features, those functions may be performable by other features whether described or not.

[0094] Although features have been described with reference to certain embodiments, those features may also be present in other embodiments whether described or not.

[0095] Whilst endeavoring in the foregoing specification to draw attention to those features of the invention believed to be of particular importance it should be understood that the Applicant claims protection in respect of any patentable feature or combination of features hereinbefore referred to and/or shown in the drawings whether or not particular emphasis has been placed thereon.

Claims

1. An optically translucent passive electromagnetic resonator for anisotropic direction of electromagnetic radiation comprising:

a ground plane;
 a reception conductor configured to receive from an exterior, electromagnetic radiation within one or more bandwidths; and
 a transmission conductor and configured to transmit to an interior, electromagnetic radiation within the one or more bandwidths;
 wherein the ground plane is optically translucent, the reception conductor is optically translucent and the transmission conductor is optically translucent;
 wherein the reception conductor, for facing the exterior, is physically separated from a first side of the ground plane by a first dielectric and is coupled to the transmission conductor to transfer electromagnetic energy within the one or more bandwidths preferentially to the transmission conductor;
 wherein the transmission conductor, for facing the interior, is physically separated from a second side of the ground plane by a second dielectric and is coupled to the reception conductor to receive electromagnetic energy within the one or more bandwidths preferentially from the reception conductor;
 and wherein the ground plane, the reception conductor and the transmission conductor are

- configured to cause the reception conductor to receive electromagnetic radiation within the one or more bandwidths preferentially from the exterior and to cause the transmission conductor to transmit electromagnetic radiation within the one or more bandwidths preferentially to the interior.
2. An optically translucent passive electromagnetic resonator as claimed in claim 1, wherein the transmission conductor has an anisotropic radiation pattern that concentrates transmitted electromagnetic radiation in a particular interior direction 54.
 3. An optically translucent passive electromagnetic resonator as claimed in any preceding claim, wherein in the ground plane, the reception conductor and the transmission conductor are configured to cause the reception conductor to receive electromagnetic radiation within one or more bandwidths from a majority of exterior directions and to cause the transmission conductor to transmit electromagnetic radiation within the one or more bandwidths preferentially towards a particular interior direction 54.
 4. An optically translucent passive electromagnetic resonator as claimed in claim 2 or 3, wherein the transmission conductor lies in a flat plane and the particular direction is normal (orthogonal) to the plane.
 5. An optically translucent passive electromagnetic resonator as claimed in claim 4, wherein the optically translucent passive electromagnetic resonator is configured such that there is signal gain within 1/2 or 1 m of the transmission conductor in the particular direction compared to an absence of the optically translucent passive electromagnetic resonator.
 6. An optically translucent passive electromagnetic resonator as claimed in any preceding claim, configured to operate without power input circuitry, power harvesting circuitry, power storage circuitry or power distribution circuitry, other than the reception conductor, the transmission conductor and any couple between the reception conductor, and the transmission conductor.
 7. An optically translucent passive electromagnetic resonator as claimed in any preceding claim, comprising one or more galvanic feeds that electrically interconnect the reception conductor and the transmission conductor.
 8. An optically translucent passive electromagnetic resonator as claimed in any preceding claim, comprising:
 - a translucent exterior-facing protective substrate, protecting the reception conductor; and
 - a translucent interior-facing protective substrate, protecting the transmission conductor, wherein the first dielectric is a translucent substrate between the reception conductor and ground plane and the second dielectric is a translucent dielectric substrate between the transmission conductor and ground plane.
 9. An optically translucent passive electromagnetic resonator as claimed in any preceding claim, wherein in the ground plane is a continuous planar conductive layer having an external ground connector.
 10. An optically translucent passive electromagnetic resonator as claimed in any preceding claim, wherein the reception conductor comprises one or more resonators arranged in a planar array and the transmission conductor comprises one or more resonators arranged in a planar array.
 11. An optically translucent passive electromagnetic resonator as claimed in any preceding claim, forming part of an adhesive window film comprising:
 - a translucent exterior-facing protective substrate protecting the reception conductor;
 - a translucent interior-facing protective substrate protecting the transmission conductor; and
 - one or more galvanic interconnections between the reception conductor and the transmission conductor, wherein the first dielectric is a translucent and located between the reception conductor and the ground plane and the second dielectric is a translucent and located between the transmission conductor and the ground plane, and wherein the translucent exterior-facing protective substrate comprises an adhesive layer.
 12. A pre-formed construction unit for placement within a building structure to improve reception within an interior of the building structure comprising a frame providing multiple fluid-separated window glass panels including at least a first window glass panel and a second different window glass panel, and comprising the optically translucent passive electromagnetic resonator as claimed in any preceding claim, wherein the first window glass panel supports the reception conductor and the second window glass panel supports the transmission conductor and wherein one or more galvanic interconnections between the reception conductor and the transmission conductor are routed via the frame.
 13. A pre-formed construction unit for placement within

a building structure to improve reception within an interior of the building structure comprising a frame providing multiple fluid-separated window glass panels including at least a first window glass panel and a second different window glass panel, and comprising the optically translucent passive electromagnetic resonator as claimed in any of claims 1 to 11, wherein the first window glass panel supports the reception conductor and the second window glass panel supports the transmission conductor and wherein

- (i) the first window glass panel supports the reception conductor on an interior or exterior surface and supports the ground plane on an interior surface, there being at least one fluid gap between the ground plane and the transmission conductor; or
- (ii) the second window glass panel supports the transmission conductor on an interior or exterior surface and supports the ground plane on an interior surface, there being at least one fluid gap between the ground plane and the reception conductor; or
- (iii) wherein an intermediate window glass panel between the first window glass panel and the second window glass panel supports the ground plane, there being at least one fluid gap between the ground plane and the reception conductor and at least one fluid gap between the ground plane and the transmission conductor.

14. A pre-formed construction unit as claimed in claim 12 or 13, further comprising an interconnection between the ground plane of the optically translucent passive electromagnetic resonator and the frame.
15. A method of providing an optically translucent passive electromagnetic resonator for anisotropic direction of electromagnetic radiation comprising:

providing an optically translucent ground plane;
 providing an optically translucent reception conductor that is configured to receive electromagnetic radiation within one or more bandwidths preferentially from an exterior;
 providing an optically translucent transmission conductor that is configured to transmit electromagnetic radiation within the one or more bandwidths preferentially to an interior;
 coupling the optically translucent reception conductor to the optically-translucent transmission conductor to enable transfer of electromagnetic energy within one or more bandwidths from the optically translucent reception conductor to the optically-translucent transmission conductor.

FIG 1

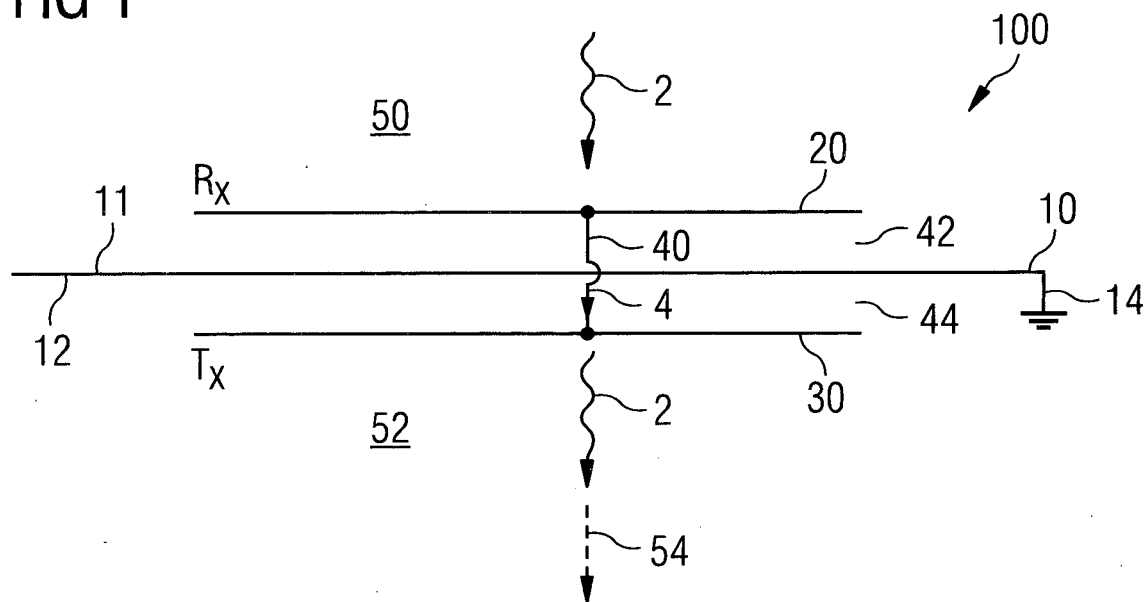


FIG 2

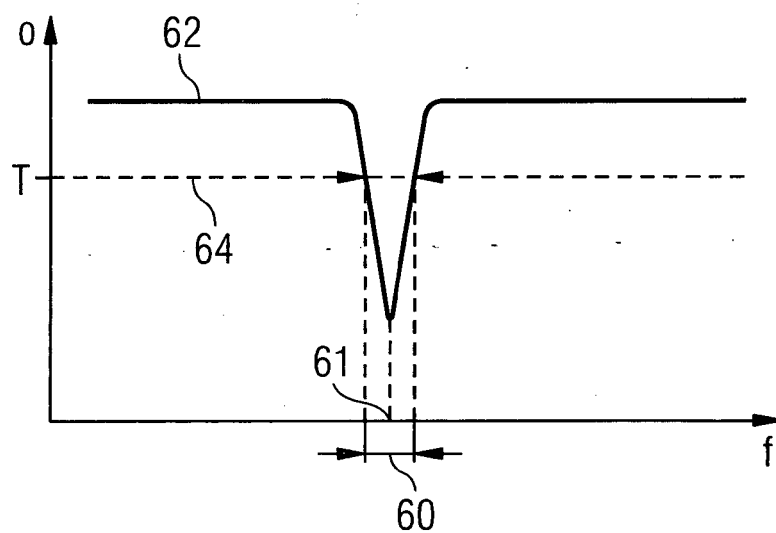


FIG 3A

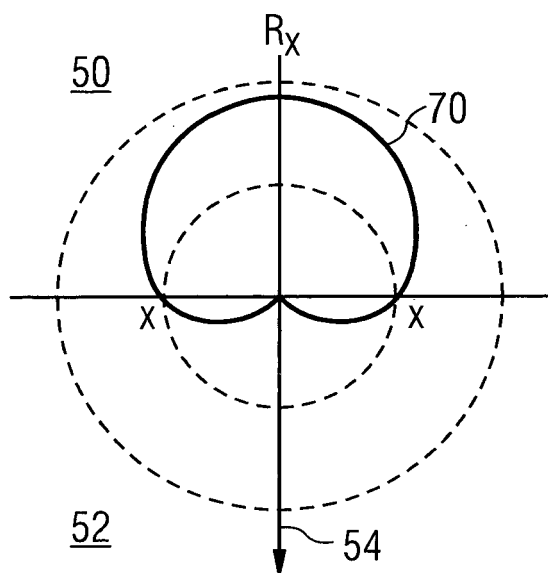


FIG 3B

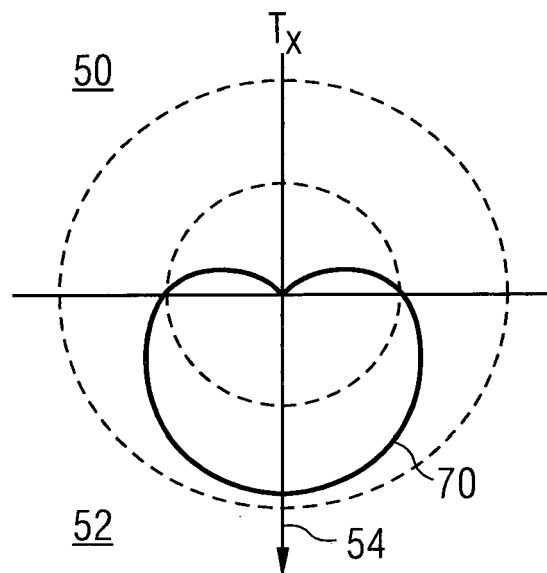


FIG 3C

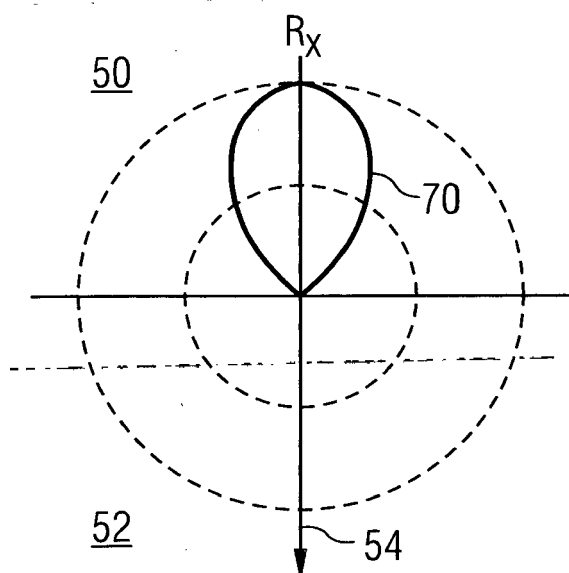


FIG 3D

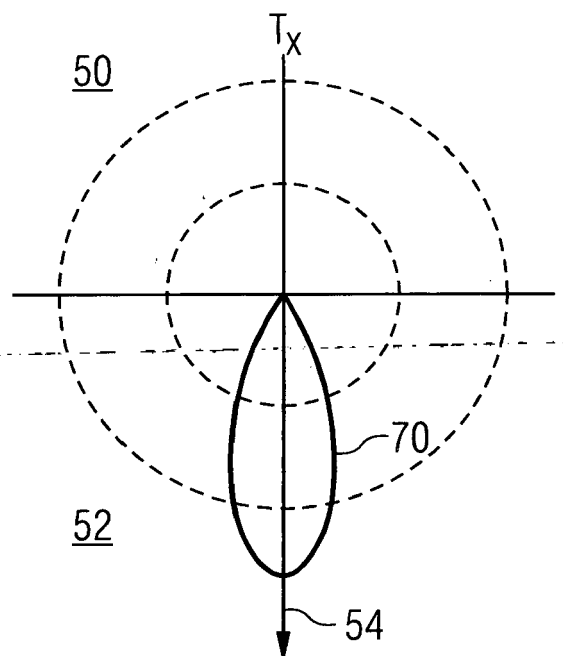


FIG 4A

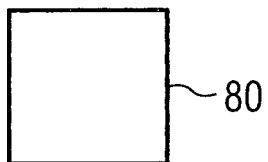


FIG 4B

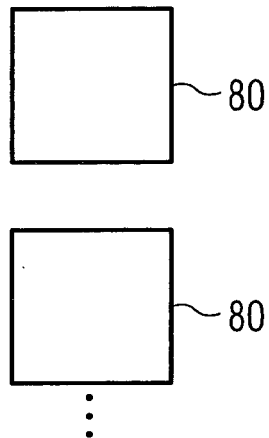


FIG 4C

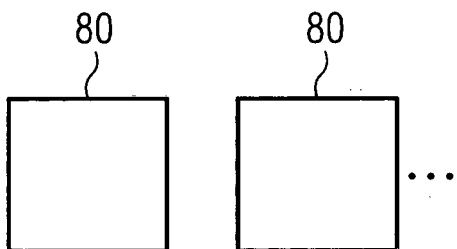


FIG 4D

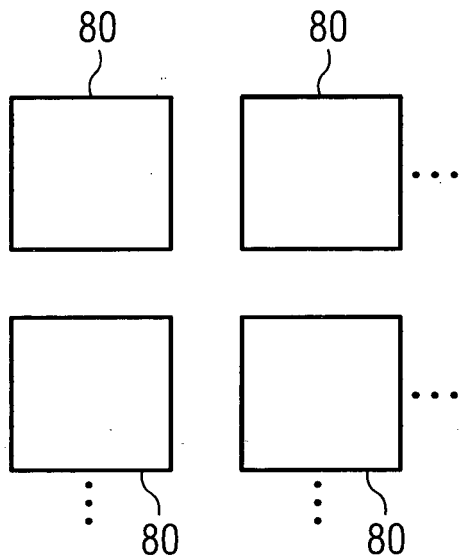


FIG 5

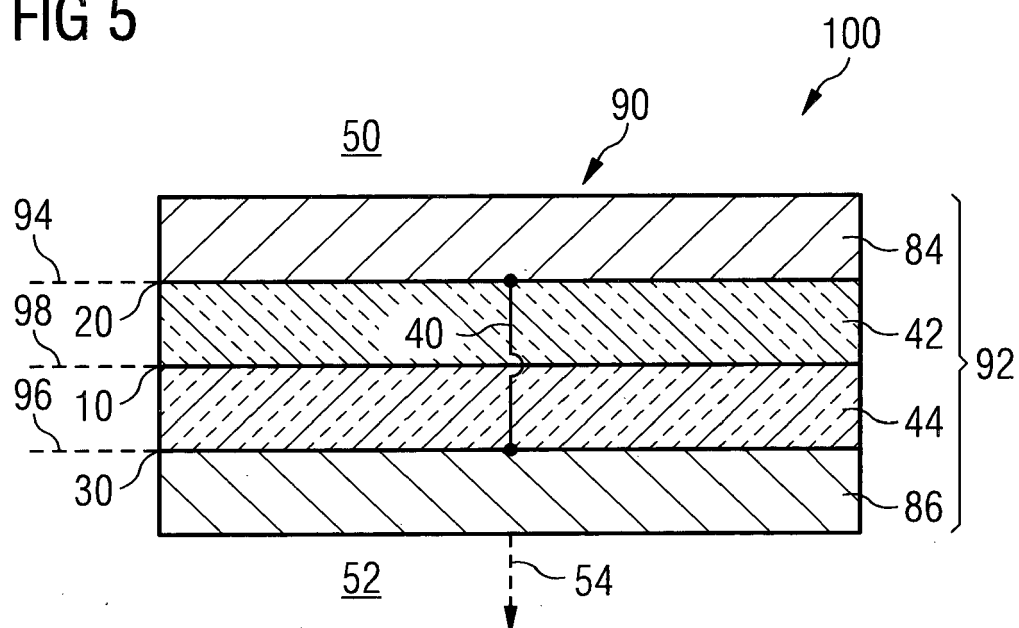


FIG 6

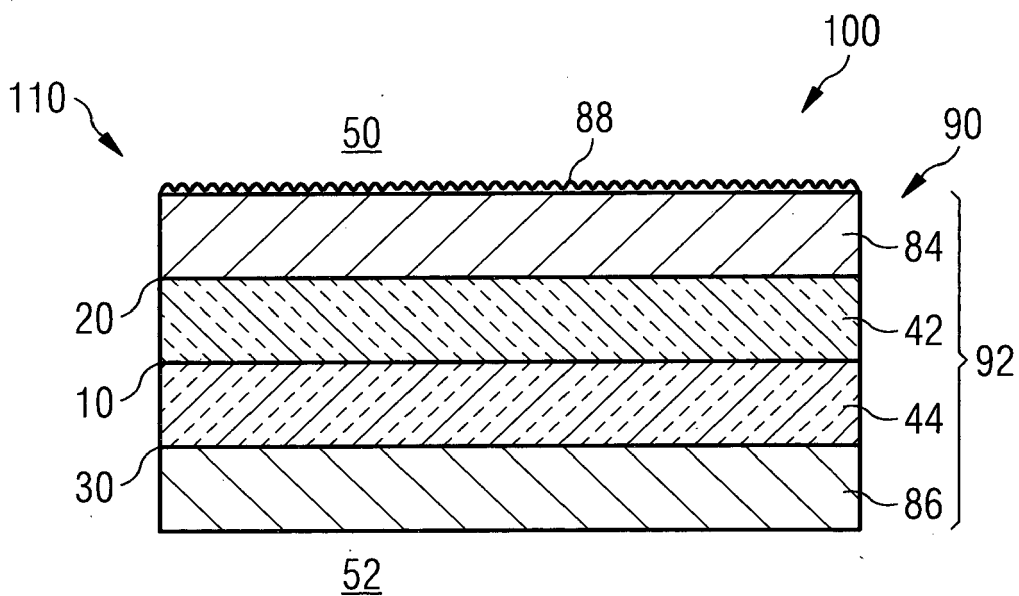


FIG 7A

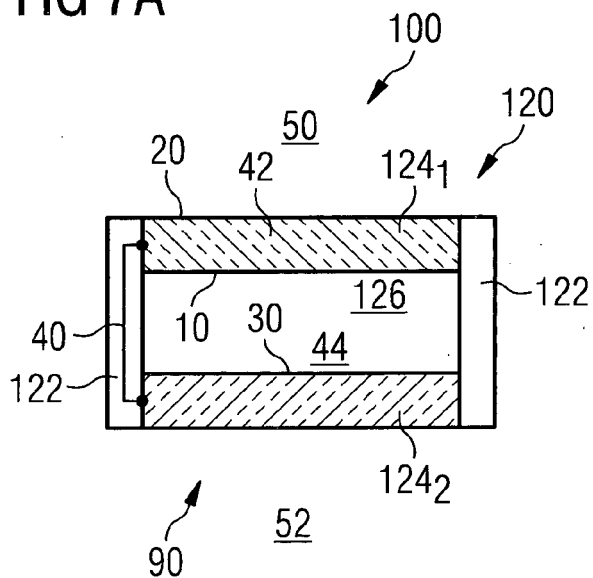


FIG 7B

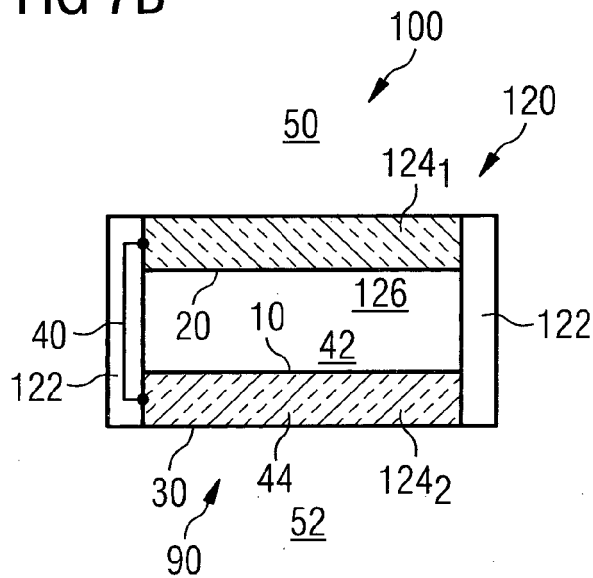


FIG 7C

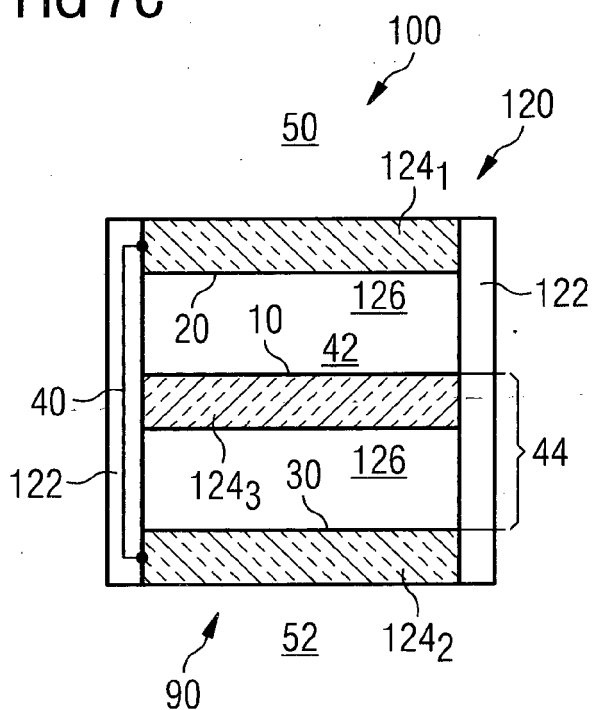


FIG 7D

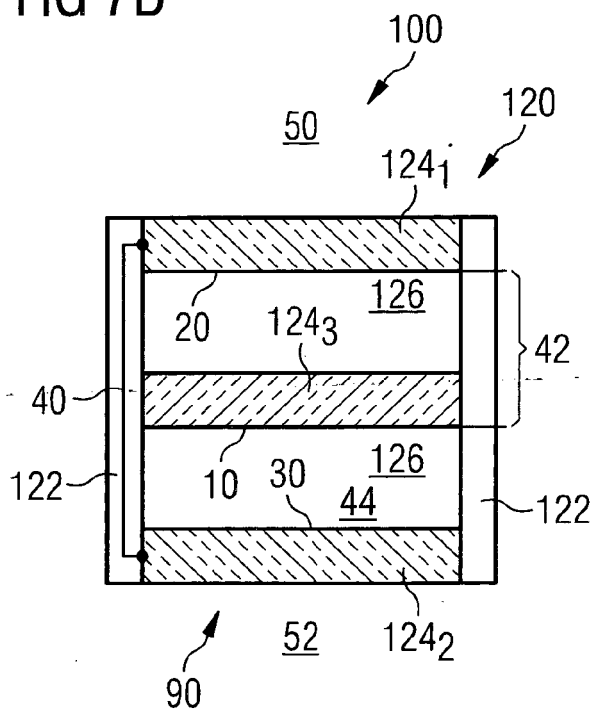


FIG 8

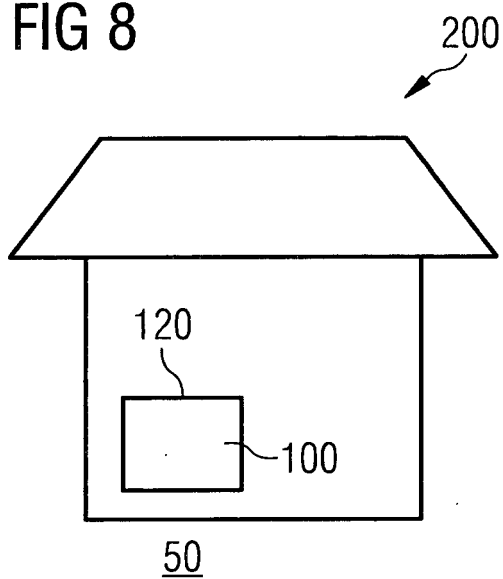
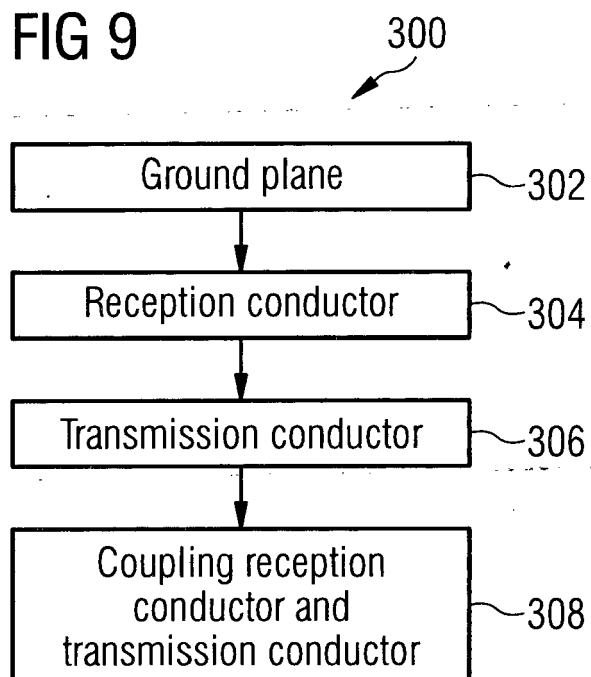


FIG 9





EUROPEAN SEARCH REPORT

Application Number
EP 17 17 0579

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			H01Q E06B
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 27 October 2017	Examiner Degraeve, Alexis
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 17 17 0579

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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27-10-2017

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