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(54) WAVEGUIDE ASSEMBLY

WELLENLEITERANORDNUNG

ENSEMBLE GUIDE D'ONDES

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- **HIDEKI KIRINO ET AL: "A 76 GHz Multi-Layered Phased Array Antenna Using a Non-Metal Contact Metamaterial Waveguide", IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, vol. 60, no. 2, 1 February 2012 (2012-02-01), USA, pages 840 - 853, XP055545959, ISSN: 0018-926X, DOI: 10.1109/TAP.2011.2173112**

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Description

[0001] The invention relates to a waveguide assembly with a waveguide and an emitter of electromagnetic waves. The waveguide may be used in a radar sensor, for example in a vehicle.

[0002] Waveguides are well known in the art for guiding electromagnetic waves, e.g., in the radiofrequency range, in a variety of apparatuses. The electromagnetic waves are often supplied to the waveguide from an emitter of electromagnetic waves coupled to a suitable electric circuit, which typically is located on a printed circuit board (PCB); an example of such waveguides can be found in US 2021 / 0 028 527 A1. The PCB in prior art is also used to close the waveguide on one side, which implies constraints for the PCB, as it has to correspond in size and shape to the waveguide. Furthermore, while a PCB has two opposite sides on which electronic components can be placed in principle, if the PCB is used to close the waveguide, placing electronic components on the side of the PCB towards the waveguide could interfere with the propagation of electromagnetic waves in the waveguide.

[0003] US 2020 / 0 076 038 A1 discloses a waveguide device with a first and a second electrical conductor each having a throughhole. Electrically conductive waveguiding walls are positioned such that they include at least a portion of the space between the throughholes. The waveguiding walls allow an electromagnetic wave to propagate between the throughholes.

[0004] The article "A 76 GHz Multi-Layered Phased Array Antenna Using a Non-Metal Contact Metamaterial Waveguide" by Hideki Kirino et al. in IEEE Transactions on Antennas and Propagation, vol. 60, no. 2, 01 February 2012, pages 840 - 853 discloses a multi-layer waveguide structure.

[0005] US 2019 / 0 006 743 A1 discloses a waveguide device module including plural waveguides and a circuit board. Applications in a vehicle are considered.

[0006] It therefore is an object of the invention to provide a waveguide assembly overcoming the above constraints.

[0007] This object is achieved by a waveguide assembly according to claim 1 or alternatively by a waveguide assembly according to claim 2. Claim 6 relates to a corresponding radar sensor and claim 7 to a corresponding vehicle.

[0008] The waveguide assembly according to the invention includes a main waveguide comprising an arrangement of electrically conductive pins protruding from a basis and a circuit with an emitter for electromagnetic waves. The basis is of an electrically conductive material and may in particular be plate-shaped. The electrically conductive pins may be integral with the basis. A plate which is different from the basis and which comprises an electrically conductive material is positioned between the main waveguide and the emitter. The plate has an opening for electromagnetic waves from the emitter to pass through the plate. Furthermore, on a side of the plate opposite the main waveguide a group of electrically conductive pins is provided. The group of pins surrounds the emitter and the opening such that the group of pins forms a first transition waveguide for passing electromagnetic radiation from the emitter through the opening. The pins of the group of pins may for example be positioned such that their positions in a plane parallel to the plate trace out an open or closed polygon.

[0009] The plate closes the waveguide at least on one side, a function which in prior art was achieved by a PCB including the emitter. As the functions of closing the waveguide and carrying circuits, including the emitter, for addressing the waveguide, are now split between the plate and a separate component, like a PCB, this separate component is not subject to constraints imposed by the shape of the waveguide. Likewise, the waveguide is not constrained in shape by requirements of the prior art PCB. It is furthermore possible to independently choose suitable materials for plate and PCB or other circuit component. If a PCB is used for the circuits and emitter, as the PCB does not now close the waveguide, electronic components can be placed on opposite sides of the PCB, not just on one side of the PCB which is not towards the waveguide. The electromagnetic waves the emitter is configured to emit may for example be in the radiofrequency range or in the range of millimetre waves.

[0010] In one alternative of the invention the pins of the group of pins surrounding the emitter, i.e., the pins forming the first transition waveguide between the emitter and the plate, extend through the plate. On the side of the plate opposite the emitter, these pins can function as additional pins of the main waveguide. Alternatively, these pins can form part of a second transition waveguide located between the plate and the main waveguide. If there is a second transition waveguide, electromagnetic waves from the emitter, guided by the first transition waveguide, are passed through the opening in the plate into the second transition waveguide, and from there the electromagnetic waves are passed on into the main waveguide.

[0011] In another alternative of the invention the waveguide assembly includes an electrically conductive block, for example a metal block, attached to the pins of the group of pins surrounding the emitter. This stabilises these pins mechanically. The conductive block is positioned in a cut-out of the plate and extends to the side of the plate where there is the main waveguide.

[0012] In an embodiment the plate is connected to the conductive block via a structure including at least one step. This allows a more reliable bonding between the plate and the conductive block by, for instance, gluing, soldering, or welding and serves to define the position of the plate relative to the block in a more stable fashion. Also, such a structure reduces electromagnetic leakage from the waveguide assembly.

[0013] A second transition waveguide may be located between the plate and the main waveguide even if the

pins of the first transition waveguide do not extend through the plate. If there is a second transition waveguide, electromagnetic waves from the emitter, guided by the first transition waveguide, are passed through the opening in the plate into the second transition waveguide, and from there the electromagnetic waves are passed on into the main waveguide.

[0014] For either alternative of the invention, in an embodiment the conductive material of the plate is a metal or a metallised plastic, i.e., a plastic substrate fully covered with a metal layer. The plate may also consist entirely of metal.

[0015] A radar sensor according to the invention has a waveguide assembly according to the invention, as described above. Such a radar sensor is less constrained in its manufacture, due to the reduced constraints on the manufacture of the waveguide assembly. This provides more freedom, for example for more efficient design.

[0016] A vehicle according to the invention has a radar sensor according to the invention, as just described. The advantages in manufacture of the radar sensor carry over to the manufacture of the vehicle. A more efficient radar sensor operates more efficiently in the vehicle and therefore contributes to safety.

[0017] Below the invention and its advantages will be described in more detail with reference to the accompanying schematic drawings.

Figure 1 shows an embodiment of a waveguide assembly according to the invention.

Figure 2 shows a further embodiment of a waveguide assembly according to the invention in a front view.

Figure 3 shows the embodiment of Fig. 2 in a side view.

Figure 4 shows a portion of a waveguide assembly according to the invention.

Figure 5 shows a portion of a waveguide assembly according to the invention.

Figure 6 shows a portion of a waveguide assembly according to the invention.

Figures 7-9 show the connection between plate and conductive block.

Figure 10 shows a vehicle with a radar sensor according to the invention.

[0018] The figures only show examples of how the invention can be implemented. In particular, the figures and the accompanying description are not to be taken as a limitation of the invention to the examples shown.

[0019] **Fig. 1** shows an embodiment of the waveguide assembly 1 according to the invention. A main waveguide 3 with pins 31 protruding from a basis 32 is closed by an electrically conductive plate 4 on a side opposite to the basis 32. A printed circuit board (PCB) 2 carries an emitter 6 for electromagnetic waves and has circuitry (not shown) for controlling the emitter 6. Between the plate 4 and the PCB 2 a first transition waveguide 5 is provided for passing electromagnetic waves from the emitter 6 through an opening (not shown) in the plate 4 into the main waveguide 3. The transition waveguide 5 has pins 51 which surround the emitter 6 at least partially.

[0020] The pins 51 extend through the plate 4 and on the side of the plate 4 opposite the PCB 2 function as additional pins of the main waveguide 3.

[0021] **Fig. 2** shows an embodiment of the waveguide assembly 1 according to the invention. The view here is a front view, i.e., electromagnetic waves in the main waveguide 3 travel in a direction orthogonal to the plane of the drawing. The main waveguide 3 has a basis 32 with pins 31. On the side of basis 32 opposite pins 31 a second transition waveguide 8 with pins 81 is provided. Conductive plate 4 closes main waveguide 3 and second transition waveguide 8 on one side towards PCB 2. A first transition waveguide 5 with pins 51 is provided between PCB 2 and plate 4. PCB 2 carries an emitter 6 for electromagnetic waves, for example implemented as a microstrip patch. Electromagnetic waves from the emitter 6, guided by first transition waveguide 5, pass plate 4 through opening 41 in the plate 4 and reach the second transition waveguide 8. From there, the electromagnetic waves are passed on into the main waveguide 3. A cover 33 closes the main waveguide 3 at the side of the pins 31. A conductive block 7 is provided between the basis 32 of the main waveguide 3 and the plate 4, to stabilise pins 51 of the first transition waveguide 5. The pins 51 are attached to block 7. Block 7 extends into a cut-out 42 in the plate 4.

[0022] **Fig. 3** shows the waveguide assembly 1 shown in Fig. 2 in a side view. The direction of propagation of electromagnetic waves in the main waveguide 3 is parallel to the plane of the drawing. All elements shown have already been discussed in the context of Fig. 2. It can be seen that the second transition waveguide 8 with pins 81 extends longer along the main waveguide 3 than the first transition waveguide 5 with pins 51. Together with Fig. 2 it is also shown how the pins 51 of the first transition waveguide 5 surround the emitter 6 for electromagnetic waves.

[0023] **Fig. 4** shows a portion of a waveguide assembly 1 according to the invention, seen from the side of the emitter 6 for electromagnetic waves. Emitter 6 is supplied with energy via supply line 61. Pins 51 of the first transition waveguide 5 here surround emitter 6 on three sides, the positions of the pins 51 tracing out a rectangle open on one side, corresponding to a "U"-shape. Pins 51 are attached to a conductive block 7, stabilising the pins 51 mechanically. On the other side of conductive plate 4, from the perspective of the drawing behind plate 4, is

second transition waveguide 8 with pins 81, part of which is also visible through opening 41 in plate 4.

[0024] **Fig. 5** shows a portion of a waveguide assembly 1 according to the invention, seen from the side of the emitter 6 for electromagnetic waves. Emitter 6 is supplied with energy via supply line 61. Most of the structure shown is covered by the PCB 2. Pins 51 of first transition waveguide 5 surround emitter 6 in a "U"-shape fashion as in the case of Fig. 4. Shown also is opening 41 in plate 4, for passing electromagnetic waves into second transition waveguide 8 with pins 81. Conductive block 7 is partially inserted in a corresponding cut-out 42 of plate 4. Also indicated is part of the main waveguide 3.

[0025] **Fig. 6** shows a portion of a waveguide assembly 1 according to the invention. Shown are pins 51 of the first transition waveguide, and conductive block 7 mechanically stabilising these pins 51. Further shown are pins 81 of the second transition waveguide and basis 32 of main waveguide 3. Also shown is plate 4, however not in its mounted position. Arrows 100 indicate how plate 4 is to be set into recesses or steps 71 provided in conductive block 7 for increased robustness and mechanical stability of the assembly.

[0026] **Figs. 7** to **9** show various possibilities of connecting the plate 4 to the conductive block 7. The connection has to be electrically conductive and can for example be realised by welding, soldering or gluing. Fig. 7 shows a simple butt joint. Fig. 8 shows a profiled connection, more precisely a single step 71. Fig. 9 shows a profiled connection, more precisely a double step 72. Single step and double step provide additional stability due to their shape and increase the contact surface between plate 4 and block 7 available for, e.g., soldering, welding, or gluing. Furthermore, a profiled connection contributes to reducing electromagnetic leakage through the connection.

[0027] **Fig. 10** shows a vehicle 500, which according to the invention has a radar sensor 400 according to the invention. The radar sensor 400 according to the invention has a waveguide assembly 1 according to the invention.

List of Reference Signs

[0028]

1	waveguide assembly
2	printed circuit board (PCB)
3	main waveguide
4	plate
5	first transition waveguide
6	emitter
7	conductive block
8	second transition waveguide
31	pin
32	basis
33	cover
41	opening
42	cut-out
51	pin
61	supply line
71	step
72	double step
81	pin
100	arrow
400	radar sensor
500	vehicle

Claims

1. Waveguide assembly (1) including

a main waveguide (3) comprising an arrangement of electrically conductive pins (31) protruding from a basis (32);
a circuit with an emitter (6) for electromagnetic waves;
a plate (4), different from the basis (32), the plate (4) comprising an electrically conductive material, the plate (4) positioned between the main waveguide (3) and the emitter (6),
the plate (4) having an opening (41) for electromagnetic waves from the emitter (6) to pass through the plate (4);
a group of conductive pins (51) on a side of the plate (4) opposite the main waveguide (3), the group of pins (51) surrounding the emitter (6) and the opening (41) such that the group of pins (51) forms a first transition waveguide (5) for passing electromagnetic radiation from the emitter (6) through the opening (41), wherein the pins (51) of the group of pins surrounding the emitter (6) extend through the plate (4).

2. Waveguide assembly (1) including

a main waveguide (3) comprising an arrangement of electrically conductive pins (31) protruding from a basis (32);
a circuit with an emitter (6) for electromagnetic waves;
a plate (4), different from the basis (32), the plate (4) comprising an electrically conductive material, the plate (4) positioned between the main waveguide (3) and the emitter (6),
the plate (4) having an opening (41) for electromagnetic waves from the emitter (6) to pass through the plate (4);
a group of conductive pins (51) on a side of the plate (4) opposite the main waveguide (3), the group of pins (51) surrounding the emitter (6) and the opening (41) such that the group of pins (51) forms a first transition waveguide (5) for passing electromagnetic radiation from the emitter (6) through the opening (41);

an electrically conductive block (7) attached to the pins (51) of the group of pins surrounding the emitter (6), wherein the conductive block (7) is positioned in a cut-out (42) of the plate (4) and extends to the side of the plate (4) on which there is the main waveguide (3).

3. Waveguide assembly (1) according to claim 2, wherein the plate (4) is connected to the conductive block (7) via a structure including at least one step (71, 72).

4. Waveguide assembly (1) according to one of the previous claims, wherein the conductive material of the plate (4) is a metal or a metallised plastic.

5. Waveguide assembly (1) according to one of the previous claims, wherein a second transition waveguide (8) is located between the plate (4) and the main waveguide (3).

6. Radar sensor (400),
characterised by
a waveguide assembly (1) according to one of the claims 1 to 5.

7. Vehicle (500),
characterised by
a radar sensor (400) according to claim 6.

Patentansprüche

1. Wellenleiteranordnung (1) umfassend

einen Hauptwellenleiter (3) mit einer Anordnung von elektrisch leitenden Stiften (31), die aus einer Basis (32) herausragen;
eine Schaltung mit einem Emitter (6) für elektromagnetische Wellen;
eine Platte (4), die sich von der Basis (32) unterscheidet, wobei die Platte (4) ein elektrisch leitendes Material umfasst und zwischen dem Hauptwellenleiter (3) und dem Emitter (6) angeordnet ist,
wobei die Platte (4) eine Öffnung (41) aufweist, durch die elektromagnetische Wellen vom Emitter (6) die Platte (4) durchdringen können;
eine Gruppe von leitenden Stiften (51) auf einer Seite der Platte (4), die dem Hauptwellenleiter (3) gegenüberliegt, wobei die Gruppe von Stiften (51) den Emitter (6) und die Öffnung (41) so umgibt, dass die Gruppe von Stiften (51) einen ersten Übergangswellenleiter (5) zum Durchlassen elektromagnetischer Strahlung vom Emitter (6) durch die Öffnung (41) bildet, wobei sich die Stifte (51) der Gruppe von Stiften, die den Emitter (6) umgeben, durch die Platte (4) erstrecken.

2. Wellenleiterbaugruppe (1) umfassend

einen Hauptwellenleiter (3) mit einer Anordnung von elektrisch leitenden Stiften (31), die aus einer Basis (32) herausragen;
eine Schaltung mit einem Emitter (6) für elektromagnetische Wellen;
eine Platte (4), die sich von der Basis (32) unterscheidet, wobei die Platte (4) ein elektrisch leitendes Material umfasst und zwischen dem Hauptwellenleiter (3) und dem Emitter (6) angeordnet ist,
wobei die Platte (4) eine Öffnung (41) aufweist, durch die elektromagnetische Wellen vom Emitter (6) die Platte (4) durchdringen können;
eine Gruppe von leitenden Stiften (51) auf einer Seite der Platte (4), die dem Hauptwellenleiter (3) gegenüberliegt, wobei die Gruppe von Stiften (51) den Emitter (6) und die Öffnung (41) so umgibt, dass die Gruppe von Stiften (51) einen ersten Übergangswellenleiter (5) zum Durchlassen elektromagnetischer Strahlung vom Emitter (6) durch die Öffnung (41) bildet;
einen elektrisch leitenden Block (7), der an den Stiften (51) der den Emitter (6) umgebenden Gruppe von Stiften befestigt ist, wobei der leitende Block (7) in einem Ausschnitt (42) der Platte (4) positioniert ist und sich zu der Seite der Platte (4) erstreckt, an der sich der Hauptwellenleiter (3) befindet.

3. Wellenleiteranordnung (1) nach Anspruch 2, wobei die Platte (4) über eine Struktur mit mindestens einer Stufe (71, 72) mit dem leitenden Block (7) verbunden ist.

4. Wellenleiteranordnung (1) nach einem der vorhergehenden Ansprüche, wobei das leitende Material der Platte (4) ein Metall oder ein metallisierter Kunststoff ist.

5. Wellenleiteranordnung (1) nach einem der vorhergehenden Ansprüche, wobei ein zweiter Übergangswellenleiter (8) zwischen der Platte (4) und dem Hauptwellenleiter (3) angeordnet ist.

6. Radarsensor (400), **gekennzeichnet durch** eine Wellenleiteranordnung (1) nach einem der Ansprüche 1 bis 5.

7. Fahrzeug (500), **gekennzeichnet durch** einen Radarsensor (400) nach Anspruch 6.

Revendications

1. Ensemble guide d'ondes (1) comprenant

un guide d'ondes principal (3) comprenant un arrangement de broches électriquement conductrices (31) faisant saillie à partir d'une base (32) ;
un circuit avec un émetteur (6) pour des ondes électromagnétiques ;
une plaque (4), différente de la base (32), la plaque (4) comprenant un matériau électriquement conducteur, la plaque (4) étant placée entre le guide d'ondes principal (3) et l'émetteur (6),
la plaque (4) comporte une ouverture (41) permettant à des ondes électromagnétiques provenant de l'émetteur (6) de traverser la plaque (4) ;
un groupe de broches conductrices (51) sur un côté de la plaque (4) opposé au guide d'ondes principal (3), le groupe de broches (51) entourant l'émetteur (6) et l'ouverture (41) de sorte que le groupe de broches (51) forme un premier guide d'ondes de transition (5) pour faire passer d'un rayonnement électromagnétique de l'émetteur (6) à travers l'ouverture (41), dans lequel les broches (51) du groupe de broches entourant l'émetteur (6) s'étendent à travers la plaque (4).

2. Ensemble guide d'ondes (1) comprenant

un guide d'ondes principal (3) comprenant un arrangement de broches électriquement conductrices (31) faisant saillie à partir d'une base (32) ;
un circuit avec un émetteur (6) pour des ondes électromagnétiques ;
une plaque (4), différente de la base (32), la plaque (4) comprenant un matériau électriquement conducteur, la plaque (4) étant placée entre le guide d'ondes principal (3) et l'émetteur (6),
la plaque (4) comporte une ouverture (41) permettant à des ondes électromagnétiques provenant de l'émetteur (6) de traverser la plaque (4) ;
un groupe de broches conductrices (51) sur un côté de la plaque (4) opposé au guide d'ondes principal (3), le groupe de broches (51) entourant l'émetteur (6) et l'ouverture (41) de sorte que le groupe de broches (51) forme un premier guide d'ondes de transition (5) pour faire passer d'un rayonnement électromagnétique de l'émetteur (6) à travers l'ouverture (41) ;
un bloc électriquement conducteur (7) fixé aux broches (51) du groupe de broches entourant l'émetteur (6), dans lequel le bloc conducteur (7) est positionné dans une découpe (42) de la plaque (4) et s'étend jusqu'au côté de la plaque (4) sur lequel se trouve le guide d'ondes principal (3).

3. Ensemble guide d'ondes (1) selon la revendication 2, dans lequel la plaque (4) est reliée au bloc conducteur (7) par une structure comprenant au moins une étape (71, 72).

4. Ensemble guide d'ondes (1) selon l'une des revendications précédentes, dans lequel le matériau conducteur de la plaque (4) est un métal ou un plastique métallisé.

5. Ensemble guide d'ondes (1) selon l'une des revendications précédentes, dans lequel un second guide d'ondes de transition (8) est situé entre la plaque (4) et le guide d'ondes principal (3).

6. Capteur radar (400), **caractérisé par** un ensemble guide d'ondes (1) selon l'une des revendications 1 à 5.

7. Véhicule (500), **caractérisé par** un capteur radar (400) selon la revendication 6.

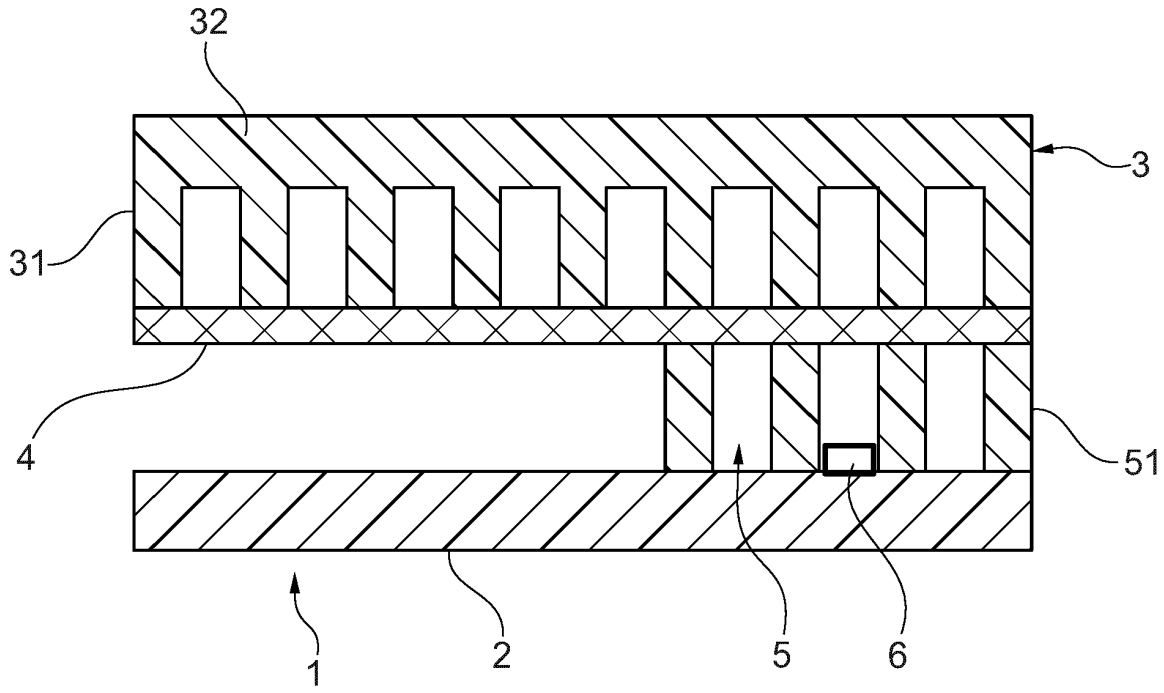

Fig. 1

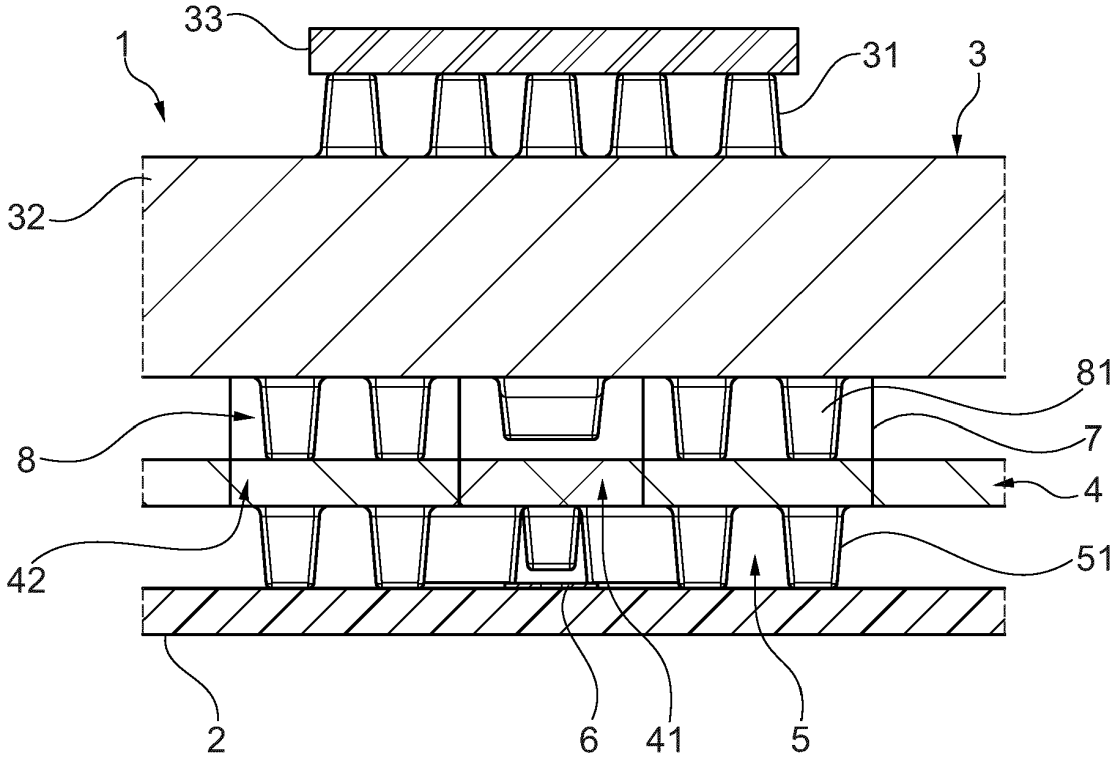

Fig. 2

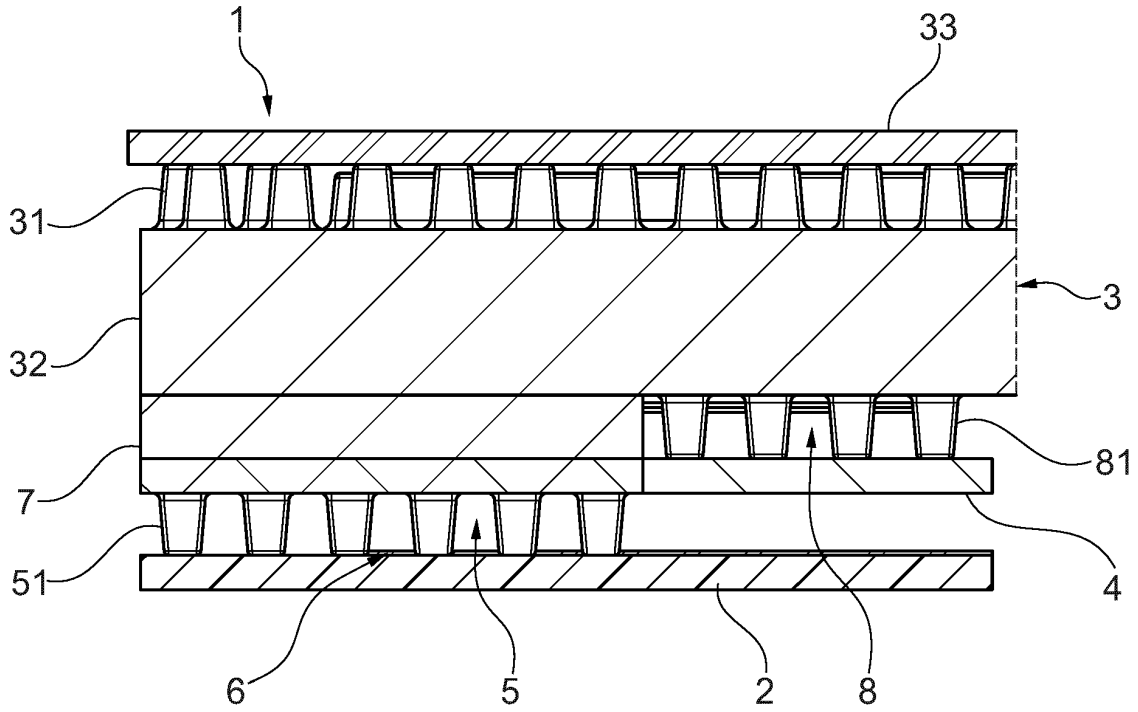

Fig. 3

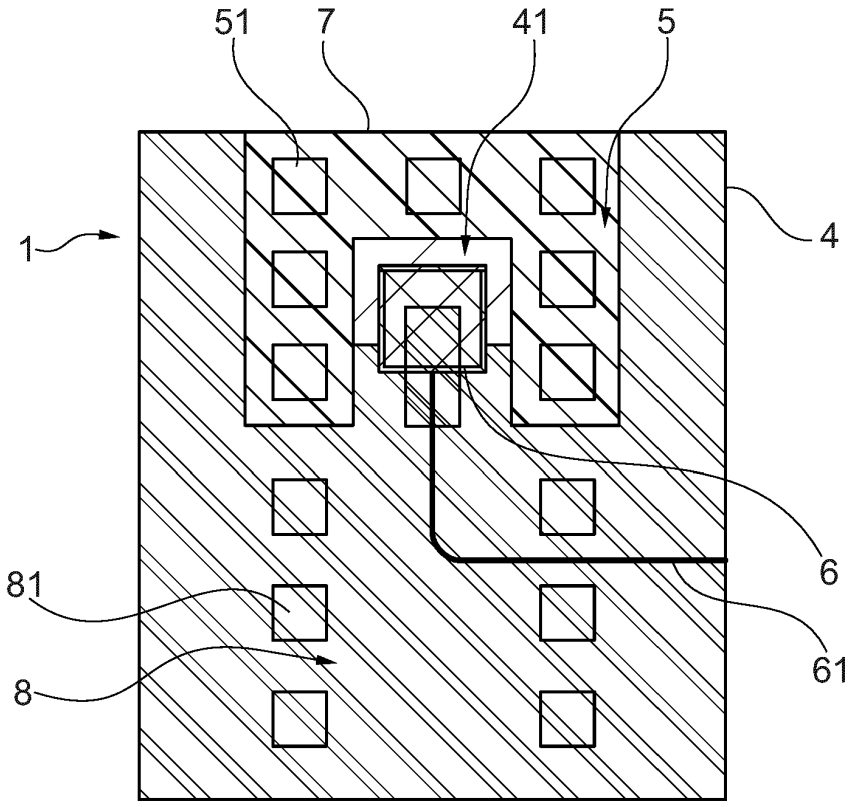

Fig. 4

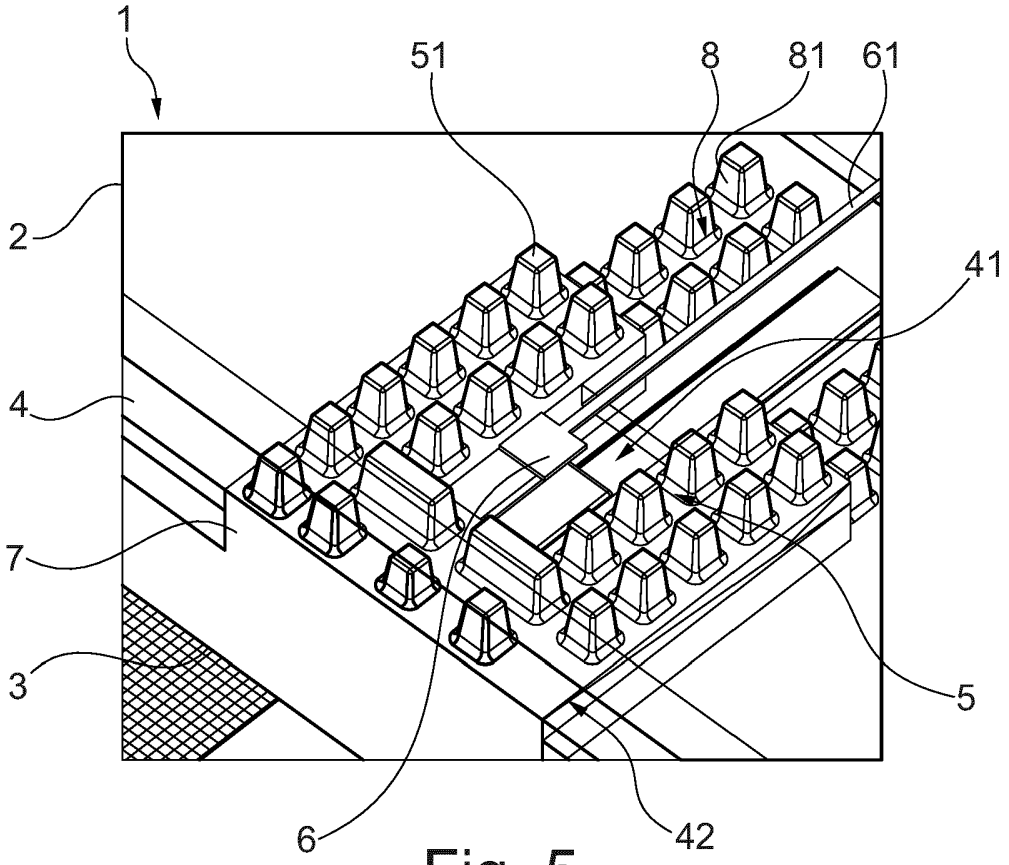

Fig. 5

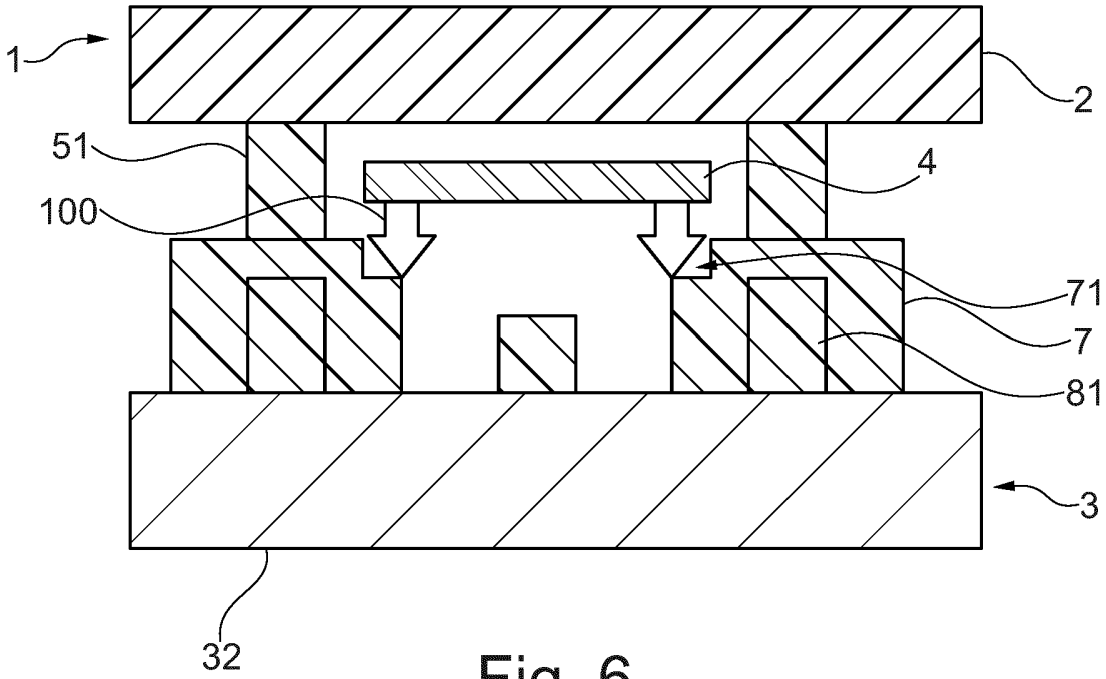

Fig. 6

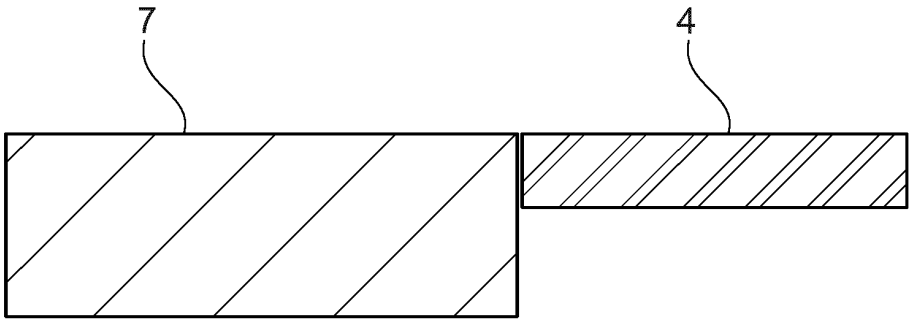

Fig. 7

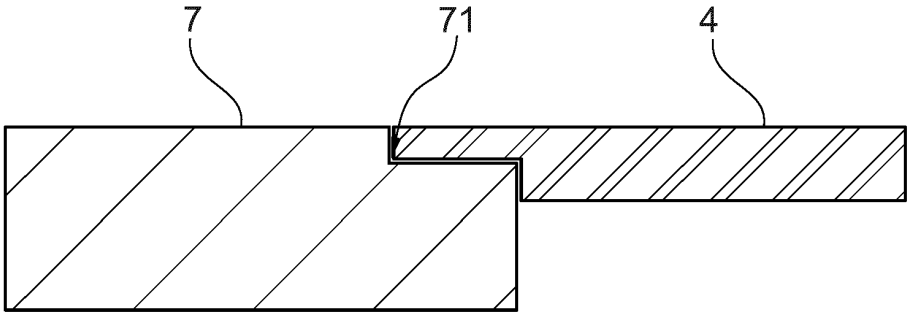

Fig. 8

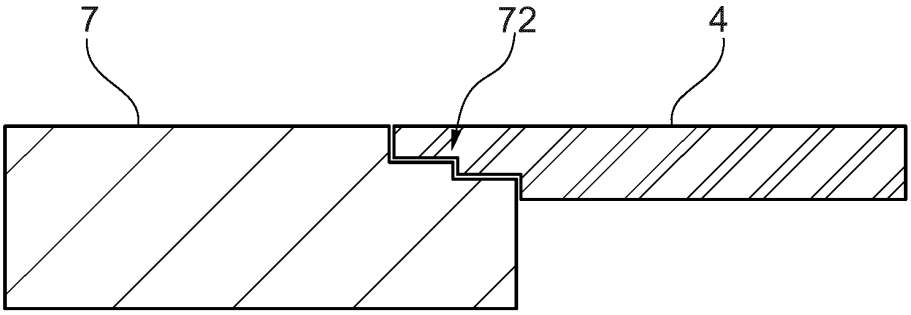

Fig. 9

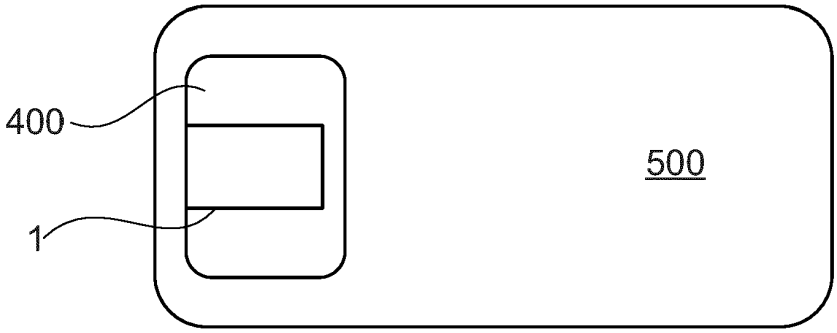

Fig. 10

REFERENCES CITED IN THE DESCRIPTION

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