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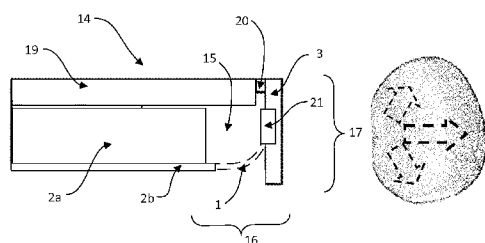


Fig. 1a

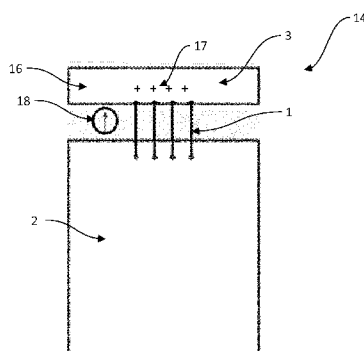


Fig. 1b

(57) Abstract: A transmission line (1) for transmitting radiofrequency range current between a first conductive element (2) and a second conductive element (3), the transmission line (1) comprising a signal current line (4) and at least one return current line (5), the signal current line (4) and the return current line(s) (5) extending in parallel. Each current line (4, 5) comprises at least one first segment (6) and at least one second segment (7). Each first segment (6) is partially aligned with at least one adjacent second segment (7), aligned segments being separated by a first dielectric gap (8), and each aligned first segment (6) and second segment (7) forming a capacitive coupling across the first dielectric gap (8). This solution enables a transmission line which provides only small capacitive loading onto its surroundings, and which therefore can extend, e.g., through an antenna element without significantly affecting the performance of the antenna element.

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TRANSMISSION LINE FOR RADIOFREQUENCY RANGE CURRENT

TECHNICAL FIELD

The disclosure relates to a transmission line for transmitting radiofrequency range current between a first conductive element and a second conductive element.

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BACKGROUND

Future electronic devices need to support millimeter-wave bands, e.g. 28 GHz and 42 GHz, as well as sub-6 GHz bands in order to accommodate increased data rates. However, the volume reserved for all the antennas in a mobile electronic device is very limited and the added millimeter-wave antennas should ideally be accommodated to the same volume as the sub-6 GHz antennas. Increasing the volume reserved for antennas would make the electronic device larger, bulkier, and less attractive to users. Current millimeter-wave antennas either require such additional volume, or if placed in the same volume, significantly reduce the efficiency of sub-6 GHz antennas.

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Current sub-6 GHz antennas are located on the metal frame of the electronic device and are of a capacitive coupling element type, a section of the metal frame being used as a capacitive coupling element antenna. The capacitive coupling element must be separated from the main conductive body of the device by a dielectric gap. The larger the gap between the metal frame and the main body, the better the performance of the sub-6 GHz antenna.

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One drawback with currently known millimeter-wave antennas for metal frame electronic devices is that the millimeter-wave antenna short-circuits the metal frame, or causes a significant capacitive loading to it. The capacitive loading effectively decreases the gap between the capacitive coupling element antenna and the main body and thus deteriorates the operation of the sub-6 GHz antenna. Short-circuiting the metal frame also deteriorates the performance of the sub-6 GHz antenna.

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Millimeter-wave antennas are conventionally placed as far as possible from the metal frame in order to not introduce additional capacitive loading. However, if the antenna is placed far from the frame, the radiation opening in the metal frame has to be comparatively large, and

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large openings in the metal frame to be avoided due to both aesthetic reasons and mechanical robustness. Furthermore, radiation from millimeter-wave antennas placed far from the frame is shadowed by the conductive components of the mobile device, which results in millimeter-wave beamforming deflecting, and thus limited beam coverage

Additionally, the trend towards very large displays, covering as much as possible of the electronic device, makes the space available for the different antennas very limited, forcing either the size of the antenna array to be significantly reduced, and its performance impaired, or a large part of the display to be inactive.

SUMMARY

It is an object to provide an improved transmission line. The foregoing and other objects are achieved by the features of the independent claims. Further implementation forms are apparent from the dependent claims, the description, and the figures.

According to a first aspect, there is provided a transmission line for transmitting radiofrequency range current between a first conductive element and a second conductive element, the transmission line comprising a signal current line and at least one return current line, the signal current line and the return current line(s) extending in parallel, each current line comprising at least one first segment and at least one second segment, each first segment being partially aligned with at least one adjacent second segment, aligned segments being separated by a first dielectric gap, each aligned first segment and second segment forming a capacitive coupling across the first dielectric gap.

This solution enables a transmission line which provides only small capacitive loading onto its surroundings, and which therefore can extend, e.g., through an antenna element formed by the first conductive element and the second conductive element without significantly affecting the performance of the antenna element. The capacitance is minimized by one or several dielectric gaps to both the signal current line and the return current line of the transmission line. Conventionally, signal lines can be equipped with gaps in case of filters, whereas return current lines are not provided with dielectric gaps because unbalanced lines are commonly used. However, in the present solution, balanced line with gaps both on signal and return paths are introduced to avoid short circuiting through the return path. The transmission line

enables allocation of the millimeter-wave antennas at the second conductive element while feeding the millimeter-wave antennas by radio circuits allocated at first conductive element. Some embodiments comprise millimeter-wave antennas coupled to the second conductive element and fed by the disclosed transmission lines across the gap between the first and the second conductive element. Further embodiments configure sub-6 GHz antennas utilizing the same first and second conductive elements. Thus, the disclosed transmission line enables both sub-6 GHz antennas and millimeter-wave antennas utilizing effectively the same volume.

In a possible implementation form of the first aspect, the first segment(s) and the second segment(s) are arranged in a first plane, each first segment partially overlapping at least one adjacent second segment, aligned and overlapping segments being separated by the first dielectric gap in a first direction within the first plane, facilitating a spatially efficient solution which comprises as many dielectric gaps as necessary in order to produce low series capacitance. The capacitance of the gap between the first conductive element and the second conductive element is minimized by a sequence comprising first segment(s), and the second segment(s) are separated by a sequence of first dielectric gap(s), i.e. a sequence of series capacitances. Hence, the performance of the sub-6 GHz antenna is maximized.

In a further possible implementation form of the first aspect, each overlap between a first segment and a second segment generates an electromagnetic coupling enabling transmission above 10 GHz frequencies and which generates electromagnetic isolation, between the first segment and the second segment, below 10 GHz. The larger the dielectric gaps, the smaller the common mode capacitance and the less the transmission line affects its surroundings.

In summary, the disclosed transmission line, comprising a signal current line and at least one return current line and wherein each line comprises overlaps between a first segment and a second segment provides the following features. The common mode capacitance between the first conductive element and the second conductive element is minimized, thus enabling high performance sub-6 GHz antennas. The differential mode transmission loss is minimized above 10 GHz frequencies, thus enabling high performance millimeter-wave antennas. Out-of-band emissions from the millimeter-wave antennas are efficiently suppressed by the frequency-selective performance of the disclosed transmission line, thus assuring compliance

of an electronic device, comprising such a transmission line, to corresponding emission standards.

In a further possible implementation form of the first aspect, each first segment and each second segment has a longitudinal extension of $\lambda/16$ to $3\lambda/4$, λ being a wavelength within the radiofrequency range. Each series capacitance of each dielectric gap is compensated with inductance of the corresponding first and second segments. Hence, the signal propagates along the transmission line without significant attenuation. When the capacitances are interleaved with inductive sections, the parasitic loading on the surrounding element is reduced and, if the surrounding element is a sub-6 GHz antenna, its operational bandwidth and efficiency is increased.

In a further possible implementation form of the first aspect, the first segment(s) further extend in a second plane and the second segment(s) further extend in a third plane, the second plane being parallel with the third plane, the second plane and the third plane being perpendicular to the first plane, allowing an as dense yet efficient transmission line as possible. The further extension in the second plane and in the third plane for the signal current line segments and for the return current line segments defines the type of transmission line. In some embodiments, two return current lines are configured with the signal current line in-between adjacent return current lines. This type of transmission line operates as a coplanar waveguide. The dimensions of the first segment(s) and the second segment(s) in the third plane as well as the spacing between signal current line segments and return current lines segments define the wave impedance of the coplanar waveguide transmission line. In alternative embodiments, one return current line is configured adjacent to the signal current line. This type of the transmission line operates as a differential balanced waveguide. The dimensions of the first segment(s) and the second segment(s) in the second and in the third plane, respectively, as well as the spacing between signal current line segments and the return current lines segments define the wave impedance of the differential balanced waveguide transmission line. In all embodiments, the wave impedances of the transmission line are defined by the dimensions of the first segment(s) and the second segment(s), minimizing the differential mode transmission loss above 10 GHz frequencies, thus enabling high performance millimeter-wave antennas.

In a further possible implementation form of the first aspect, each first segment is separated from an adjacent first segment by a second dielectric gap in a first direction within the second plane, and each second segment is separated from an adjacent second segment by a second dielectric gap in a first direction within the third plane, further minimizing the common mode capacitance between the first conductive element and the second conductive element. In some embodiments, the first segment(s) comprised in the signal current line are separated from adjacent first segment(s) comprised in the return current line by a second dielectric gap. The gap defines the wave impedance of the transmission line, thus minimizing differential mode transmission loss above 10 GHz frequencies, and enabling high performance millimeter-wave antennas.

In a further possible implementation form of the first aspect, the first segment(s) of the signal current line and the first segment(s) of the return current line(s) extend in parallel in the second plane, and the second segment(s) of the signal current line and the second segment(s) of the return current line(s) extend in parallel in the third plane, allowing both the signal current line and the return current line to be arranged in the same two parallel planes and the structure to be essentially two-dimensional due to the small distance between the two planes. This topology reduces the volume occupied by the transmission line, thus reducing the volume of the antenna within the electronic device.

In a further possible implementation form of the first aspect, the transmission line comprises one signal current line and one return current line, facilitating a balanced transmission line suitable for, e.g., balanced antennas.

In a further possible implementation form of the first aspect, each current line comprises one first segment and one second segment, the first segment being additionally separated from the second segment by a third dielectric gap in a second direction within the first plane, the second direction being perpendicular to the first direction, allowing the signal current line to extend in one plane and the return current line to extend in a further, parallel plane and the structure to be essentially three-dimensional. This topology further reduces the volume occupied by the transmission line, thus reducing the volume of the antenna within the electronic device.

In a further possible implementation form of the first aspect, the transmission line comprises one signal current line and two return current lines, the signal current line extending between the two return current lines, which is advantageous since transitions between conventional ungrounded coplanar waveguide and grounded transmission lines have low loss wide
5 frequency band performance and occupies minimum volume . This topology also provides highly confined electric fields in the line, isolating the line from its environment.

In a further possible implementation form of the first aspect, the signal current line and the return current line are connected by a first conductive structure and a second conductive
10 structure, a transmission line gap extending between the first conductive structure and the second conductive structure, the transmission line gap dividing the transmission line into a first transmission line part and a second transmission line part, the first conductive structure and the second conductive structure forming an inductive coupling between the first
15 transmission line part and the second transmission line part. Relying on inductive coupling instead of capacitive coupling to transfer the signal may be advantageous since inductive loading generally predominates when designing a matching circuit for capacitive coupling elements. Furthermore, high frequency selectivity is enabled by inductive coupling between the first transmission line part and the second transmission line part, with impedance
20 matching configured by the resonant capacitive gaps between the first and second segments. The high frequency selectivity efficiently suppresses out-of-band emissions from the millimeter-wave antennas, thus assuring compliance of the electronic device to corresponding emission standards.

According to a second aspect, there is provided an electronic device comprising a first
25 conductive element and a second conductive element separated by a non-conductive volume, a first antenna and a second antenna configured at least partially within the non-conductive volume and/or the second conductive element, a first transmission line connecting the first conductive element to the first antenna across the non-conductive volume, and at least one
30 second transmission line according to the above connecting the first conductive element to the second antenna across the non-conductive volume, each second transmission line introducing a parasitic capacitive load below 0.2 pF to a space formed by the non-conductive volume. The disclosed transmission line enables both a first antenna and a second antenna effectively utilizing the same volume.

Conventionally, return current lines are not provided with dielectric gaps since such an interruption in current is undesired due to it generating unintentional radiation which reduces the efficiency of the element comprising the return current line 5. However, in the present solution, such radiation may form part of the radiofrequency radiation generated by the first antenna and the second antenna. By allowing said transmission line to extend across the non-conductive volume, which volume forms part of the first antenna, two different antennas can be placed within the same volume, significantly reducing the space required for antennas within the electronic device.

10 In a possible implementation form of the second aspect, the electronic device further comprises a display, the first conductive element being a device chassis or a printed circuit board, the second conductive element being a metal frame, the display and the metal frame at least partially surrounding the device chassis and the printed circuit board, wherein radiofrequency radiation generated by the first antenna and the second antenna is
15 transmitted through a dielectric gap separating the display and the metal frame. The present solution is suitable for solid metal frame electronic devices, in which no slots or cuts are required. Radiation is transmitted using the gap between display and metal frame, which enables display direction and end-fire beamforming and hence full-sphere omni coverage which is not blocked by the hand of the user of the electronic device. Furthermore, a ground
20 plane of a conventional transmission line is not needed, and therefore the metal frame is not shorted.

In a further possible implementation form of the second aspect, the first antenna is a sub-6 GHz antenna, facilitating use of the present solution for current cellular bands and networks.

25 In a further possible implementation form of the second aspect, the second antenna is a millimeter-wave antenna, and a millimeter-wave antenna module is arranged between the first conductive element and the second conductive element. This solution enables the coexistence of sub-6 GHz antennas with millimeter -wave antennas, since the transmission line facilitates
30 transfer of millimeter-wave signal from the millimeter-wave module to the antenna element on the metal frame. The coexistence of sub-6 GHz antennas with millimeter -wave antennas enables communication, by the electronic device, in 5G and beyond 5G cellular networks and wireless area networks.

This and other aspects will be apparent from and the embodiments described below.

BRIEF DESCRIPTION OF THE DRAWINGS

5 In the following detailed portion of the present disclosure, the aspects, embodiments and implementations will be explained in more detail with reference to the example embodiments shown in the drawings, in which:

Fig. 1a shows a schematic cross-sectional illustration of an electronic device in accordance with
10 one embodiment of the present invention;

Fig. 1b shows a schematic top view of the embodiment of Fig. 1a;

Fig. 2 shows a perspective view of the planes of the present invention;
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Fig. 3a shows a perspective view of a transmission line in accordance with one embodiment of the present invention;

Fig. 3b shows a side view of the embodiment of Fig. 3a;
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Fig. 3c shows a top view of a part of the embodiment of Figs. 3a-3b;

Fig. 3d shows a top view of a further part of the embodiment of Figs. 3a-3b;

25 Fig. 4a shows a perspective view of a transmission line in accordance with a further embodiment of the present invention;

Fig. 4b shows a side view of the embodiment of Fig. 4a;

30 Fig. 4c shows a top view of a part of the embodiment of Figs. 4a-4b;

Fig. 4d shows a top view of a further part of the embodiment of Figs. 4a-4b;

Fig. 5a shows a perspective view of a transmission line in accordance with a yet another embodiment of the present invention;

Fig. 5b shows a top view of a part of the embodiment of Fig. 5a;

Fig. 6a shows a circuit model of the embodiments shown in Figs. 3a-3d and 5a-5b;

Fig. 6b shows a circuit model of the embodiment shown in Figs. 4a-4d;

Fig. 6c shows a circuit model comprising a transmission line in accordance with a further embodiment of the present invention;

Fig. 7 shows dimensions of the embodiment of Figs. 3a-3d.

DETAILED DESCRIPTION

Figs. 1a-1b shows an electronic device 14 comprising a display 19, a first conductive element 2, a second conductive element 3, a first antenna 16, and a second antenna 17. The first conductive element 2 may be a device chassis 2a or a printed circuit board (PCB) 2b, and the second conductive element 3 may be a metal frame. The display 19 and the metal frame 3 may at least partially surround the device chassis 2a and the printed circuit board 2b. Radiofrequency radiation generated by the first antenna 16 and the second antenna 17 may be transmitted through a dielectric gap 20 separating the display 19 and the metal frame 3.

The first conductive element 2 and the second conductive element 3 are separated by a non-conductive volume 15, the first antenna 16 and the second antenna 17 are configured at least partially within the non-conductive volume 15 and/or the second conductive element 3. A first transmission line 18 connects the first conductive element 2 to the first antenna 16 across the non-conductive volume 15, and at least one second transmission line 1, described in more detail further below, connects the first conductive element 2 to the second antenna 17 across the non-conductive volume 15. Each second transmission line 1 introduces a parasitic capacitive load below 0.2 pF to a space formed by the non-conductive volume 15.

In one embodiment, the first antenna 16 is a sub6-GHz antenna, and hence the first transmission line 18 is a sub6-GHz feed. In a further embodiment, the second antenna 17 is at least one millimeter-wave antenna. A plurality of second antennas 17 may form an antenna array. A millimeter-wave antenna module 21 may be arranged between the first conductive element 2 and the second conductive element 3.

The above-mentioned transmission line 1 is adapted for transmitting radiofrequency range current between the first conductive element 2 and the second conductive element 3. The transmission line 1, shown in Figs. 3a-6, comprises a signal current line 4 and at least one return current line 5, the signal current line 4 and the return current lines 5 extending in parallel. The transmission line 1 introduces a very low capacitive load to the first antenna 16 which enables feeding the second antenna 17, the millimeter-wave antenna, without degrading the performance of the first antenna 16, the sub6-GHz antenna, allowing both antennas to coexist within the same space.

Both the signal current line 4 and the return current line 5 comprises at least one first segment 6 and at least one second segment 7, arranged such that each first segment 6 is partially aligned with at least one adjacent second segment 7, and such that aligned segments are separated by a first dielectric gap 8. Each aligned first segment 6 and second segment 7 forms a capacitive coupling across the first dielectric gap 8. The return current line 5 is part of the ground used for the second antenna 17. Conventionally, return current line 5 are not provided with dielectric gaps since such an interruption in current is undesired due to it generating unintentional radiation which reduced the efficiency of the element comprising the return current line 5. However, in the present solution, such radiation forms part of the radiofrequency radiation generated by the first antenna 16 and the second antenna 17.

The first segments 6 and the second segments 7 may be arranged in a first plane P1, the planes referred to below being best shown in Fig. 2. Each first segment 6 partially overlaps at least one adjacent second segment 7, such that aligned and overlapping segments are separated by the first dielectric gap 8 in a first direction P1a within the first plane P1. Each overlap between a first segment 6 and a second segment 7 may generate an electromagnetic coupling enabling transmission above 10 GHz frequencies and which generates electromagnetic isolation, between the first segment 6 and the second segment 7, below 10 GHz. This is

achieved by minimizing the common mode capacitance of the transmission line 1, which is done introducing series capacitances < 0.05 pF, i.e. dielectric gaps, to the transmission line 1. The above-mentioned millimeter-wave antenna 17 array may have 4 to 8 transmission lines, in which case the parasitic capacitance of each transmission line should be below 0.1 pF to

0.2 pF.

In one embodiment, each first segment 6 and each second segment 7 has a longitudinal extension, with lengths optimized to compensate for the series capacitances within the pass band. In one embodiment, the lengths are between $\lambda/16$ and $3*\lambda/4$, λ being a wavelength within the radiofrequency range of the millimeter-wave antenna 17. The series capacitances are compensated by the comparatively short dimensions of the first segments 6 and the second segments 7. In some embodiments, the operating frequency range of the millimeter-wave antenna 17 is within the 24 GHz to 70 GHz range. For example, the longitudinal extension of each first segment 6 and each second segment 7 may be 0.5 mm to 2 mm for the frequency bands 24 GHz to 29.5 GHz.

The first segments 6 may further extend in a second plane P2 and the second segments 7 may further extend in a third plane P3, the second plane P2 being parallel with the third plane P3, and the second plane P2 and the third plane P3 being perpendicular to the first plane P1.

In some embodiments, each first segment 6a is separated from an adjacent first segment 6b by a second dielectric gap 9a in a first direction P2a within the second plane P2, and each second segment 7a is separated from an adjacent second segment 7b by a second dielectric gap 9b in a first direction P3a within the third plane P3.

The first segments 6 of the signal current line 4 and the first segments 6 of the return current lines 5 may extend in parallel in the second plane P2, and the second segments 7 of the signal current line 4 and the second segments 7 of the return current lines 5 may extend in parallel in the third plane P3, as shown in Figs. 3a-3d and 4a-4d.

Fig. 7 indicates approximate dimensions for the different elements of the transmission line 1 shown in Figs. 3a-3d, which dimensions are explained in more detail in the table below.

Dimension	Length	Description
M1	$<\lambda/4$	Short inductive transmission line compensates for the introduced capacitance.
M2	$\sim\lambda/8 - \lambda/50$	Coupled segments between transmission lines will affect the capacitive loading introduced and will define the insertion loss at mm-wave frequencies.
M3	$\sim\lambda/4$	Distance between coupled segments in different planes will determine the capacitive loading introduced and will define the insertion loss at mm-wave frequencies.
M4	$\sim\lambda/4$	Inductive sections period.
M5	-	Width of each line. Defines the differential mode impedance and common mode capacitance.
M6	-	Distance between the lines. Defines differential mode impedance.

As shown in Figs. 3a-3d and 5a-5b, the transmission line 1 may be a balanced transmission line 1 without a ground plane, comprising one signal current line 4 and one return current line 5. Figs. 3a-3d show an embodiment where both current lines 4, 5 extend in both planes P2 and P3, which planes are arranged in parallel. Figs. 5a-5b show an embodiment where the current lines 4, 5 extend in one plane P1 each, the two planes P1 extending in parallel.

As shown in Figs. 5a-5b, each current line 4, 5 may comprise one first segment 6 and one second segment 7, the first segment 6 being additionally separated from the second segment 7 by a third dielectric gap 10 in a second direction P1b within the first plane P1, the second direction P1b being perpendicular to the first direction P1a. Such an embodiment may be a so-called n-stage inter-digital capacitor.

In one embodiment, shown in Figs. 4a-4d, the transmission line 1 comprises one signal current line 4 and two return current lines 5, the signal current line 4 extending between the two return current lines 5. The arrangement may be symmetrical, but is not balanced. This embodiment may be a so-called coplanar waveguide transmission line (CPW).

Figs. 6a-6c show circuit model of the different embodiments, all models comprising, except for the elements indicated by reference numerals, a ground, a stripline, and at least one balun. Fig. 6a shows a circuit model of the embodiment shown in Figs. 3a-3d and 5a-5b, and Fig. 6b shows a circuit model of the embodiment shown in Figs. 4a-4d.

Fig. 6c shows a further embodiment wherein the signal current line 4 and the return current line 5 are connected by a first conductive structure 11 and a second conductive structure 12. A transmission line gap 13 extends between the first conductive structure 11 and the second conductive structure 12, such that the transmission line gap 13 divides the transmission line 1 into a first transmission line part 1a and a second transmission line part 1b. The first conductive structure 11 and the second conductive structure 12 together form an inductive coupling between the first transmission line part 1a and the second transmission line part 1b. Both the signal current line 4 and return current line 5 include reactive matching segments, configured for impedance matching of the lines with the conductive structures and reduction of the return loss within the frequency pass band. The reactive matching segments are implemented as planar or interdigital capacitors.

The various aspects and implementations have been described in conjunction with various embodiments herein. However, other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed subject-matter, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word “comprising” does not exclude other elements or steps, and the indefinite article “a” or “an” does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

The reference signs used in the claims shall not be construed as limiting the scope.

CLAIMS

1. A transmission line (1) for transmitting radiofrequency range current between a first conductive element (2) and a second conductive element (3), said transmission line (1) comprising
a signal current line (4) and at least one return current line (5),
said signal current line (4) and said return current line(s) (5) extending in parallel,
each current line (4, 5) comprising at least one first segment (6) and at least one second segment (7),
each first segment (6) being partially aligned with at least one adjacent second segment (7), aligned segments being separated by a first dielectric gap (8),
each aligned first segment (6) and second segment (7) forming a capacitive coupling across said first dielectric gap (8).
2. The transmission line (1) according to claim 1, wherein said first segment(s) (6) and said second segment(s) (7) are arranged in a first plane (P1),
each first segment (6) partially overlapping at least one adjacent second segment (7), aligned and overlapping segments being separated by said first dielectric gap (8) in a first direction (P1a) within said first plane (P1).
3. The transmission line (1) according to claim 1 or 2, wherein each overlap between a first segment (6) and a second segment (7) generates an electromagnetic coupling enabling transmission above 10 GHz frequencies and which generates electromagnetic isolation, between said first segment (6) and said second segment (7), below 10 GHz.
4. The transmission line (1) according to any one of the previous claims, wherein each first segment (6) and each second segment (7) has a longitudinal extension of $\lambda/16$ to $3*\lambda/4$, λ being a wavelength within said radiofrequency range.
5. The transmission line (1) according to any one of the previous claims, wherein said first segment(s) (6) further extend in a second plane (P2) and said second segment(s) (7) further extend in a third plane (P3), said second plane (P2) being parallel with said third plane (P3),

said second plane (P2) and said third plane (P3) being perpendicular to said first plane (P1).

6. The transmission line (1) according to claim 5, wherein each first segment (6a) is separated from an adjacent first segment (6b) by a second dielectric gap (9a) in a first direction (P2a) within said second plane (P2), and each second segment (7a) is separated from an adjacent second segment (7b) by a second dielectric gap (9b) in a first direction (P3a) within said third plane (P3).

7. The transmission line (1) according to claim 5 or 6, wherein said first segment(s) (6) of said signal current line (4) and said first segment(s) (6) of said return current line(s) (5) extend in parallel in said second plane (P2), and said second segment(s) (7) of said signal current line (4) and said second segment(s) (7) of said return current line(s) (5) extend in parallel in said third plane (P3).

8. The transmission line (1) according to any one of the previous claims, comprising one signal current line (4) and one return current line (5).

9. The transmission line (1) according to any one of claims 1 to 4 and claim 8, wherein each current line (4, 5) comprises one first segment (6) and one second segment (7), said first segment (6) being additionally separated from said second segment (7) by a third dielectric gap (10) in a second direction (P1b) within said first plane (P1), said second direction (P1b) being perpendicular to said first direction (P1a).

10. The transmission line (1) according to any one of claims 1 to 7, comprising one signal current line (4) and two return current lines (5), said signal current line (4) extending between said two return current lines (5).

11. The transmission line (1) according to any one of the previous claims, wherein said signal current line (4) and said return current line (5) are connected by a first conductive structure (11) and a second conductive structure (12), a transmission line gap (13) extending between said first conductive structure (11) and said second conductive structure (12), said transmission line gap (13) dividing said transmission line (1) into a first transmission line part

(1a) and a second transmission line part (1b), said first conductive structure (11) and said second conductive structure (12) forming an inductive coupling between said first transmission line part (1a) and said second transmission line part (1b).

5 12. An electronic device (14) comprising

- a first conductive element (2) and a second conductive element (3) separated by a non-conductive volume (15),

-a first antenna (16) and a second antenna (17) configured at least partially within said non-conductive volume (15) and/or said second conductive element (3),

10 -a first transmission line (18) connecting said first conductive element (2) to said first antenna (16) across said non-conductive volume (15), and

-at least one second transmission line (1) according to any one of claims 1 to 11 connecting said first conductive element (2) to said second antenna (17) across said non-conductive volume (15).

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13. The electronic device (14) according to claim 12, further comprising a display (19), said first conductive element (2) being a device chassis (2a) or a printed circuit board (2b), said second conductive element (3) being a metal frame, said display (19) and said metal frame (3) at least partially surrounding said device chassis (2a) and said printed circuit board (2b),

20 wherein radiofrequency radiation generated by said first antenna (16) and said second antenna (17) is transmitted through a dielectric gap (20) separating said display (19) and said metal frame (3).

14. The electronic device (14) according to claim 12 or 13, wherein said first antenna (16) is a sub6-GHz antenna.

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15. The electronic device (14) according to any one of claims 12 to 14, wherein said second antenna (17) is a millimeter-wave antenna, and wherein a millimeter-wave antenna module (21) is arranged between said first conductive element (2) and said second conductive element (3).

30

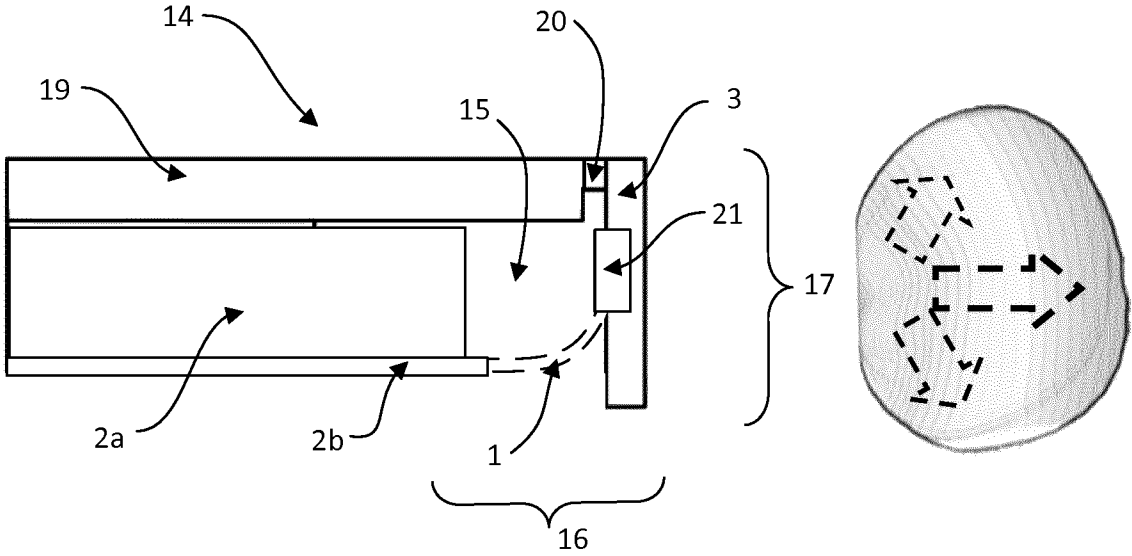


Fig. 1a

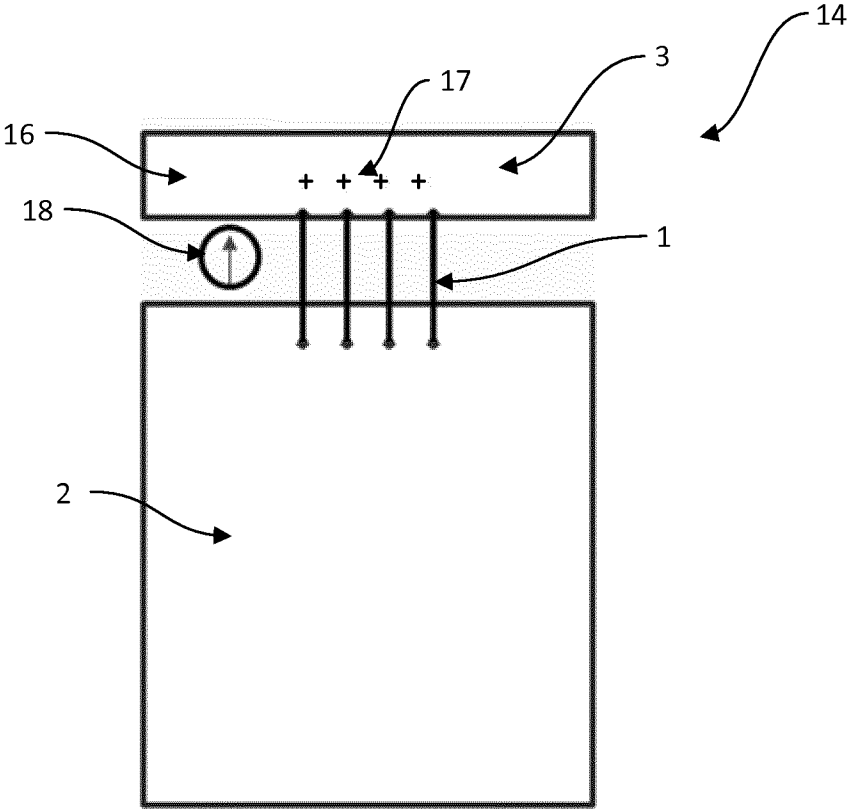


Fig. 1b

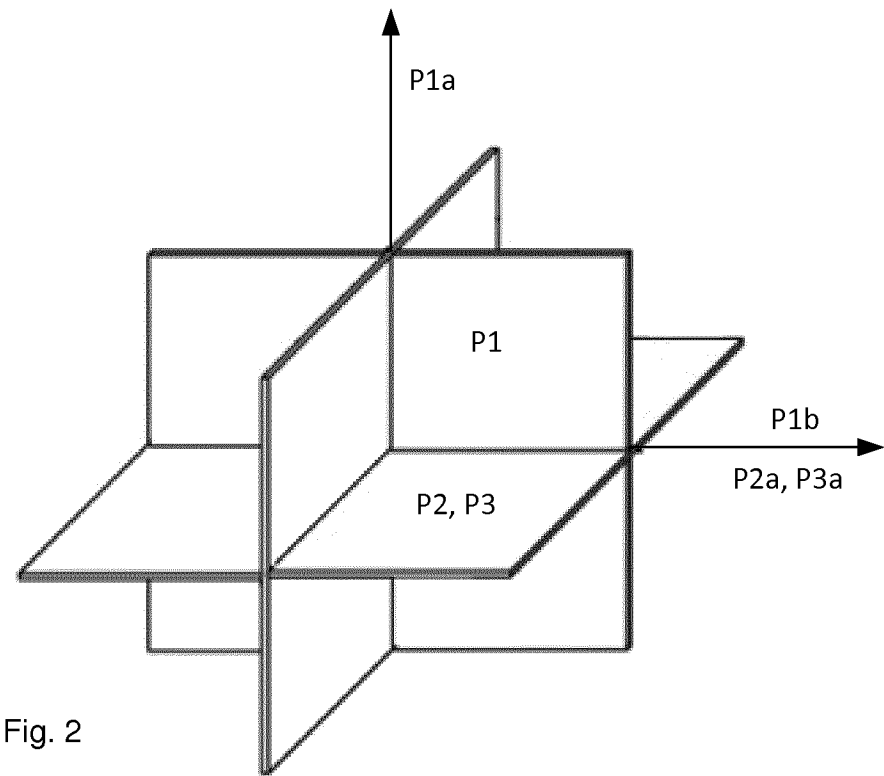


Fig. 2

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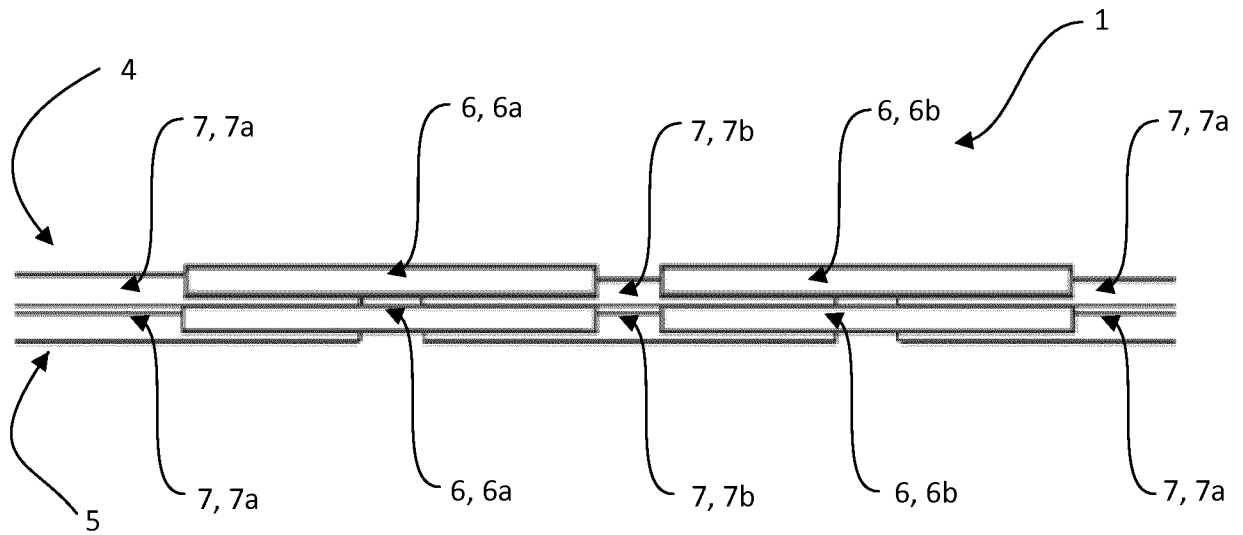


Fig. 3a

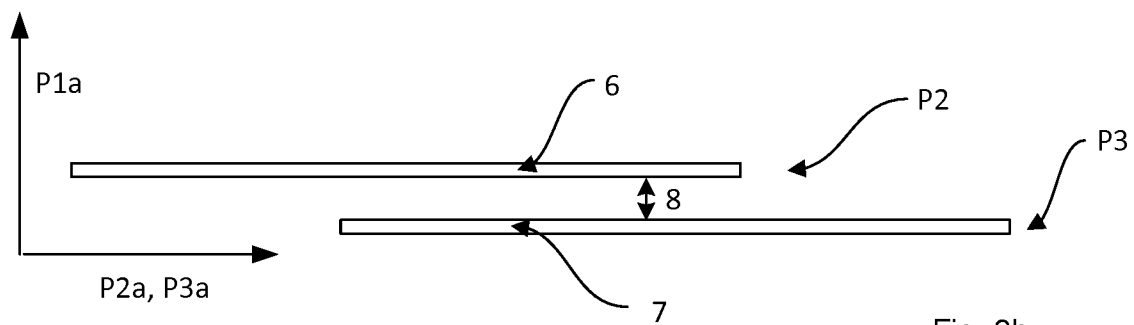


Fig. 3b

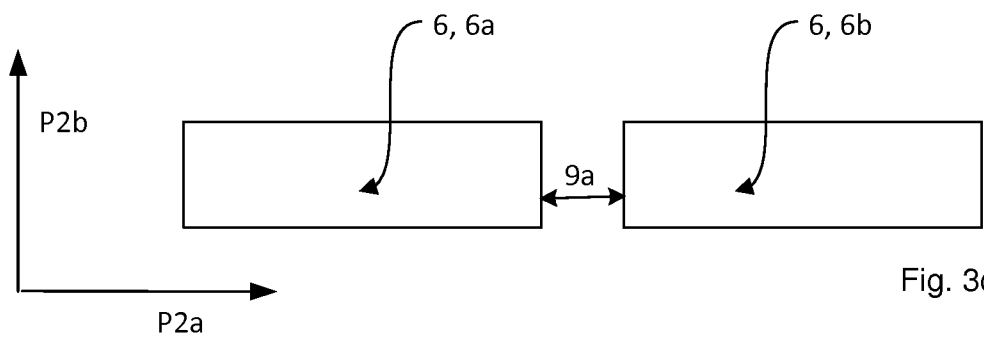


Fig. 3c

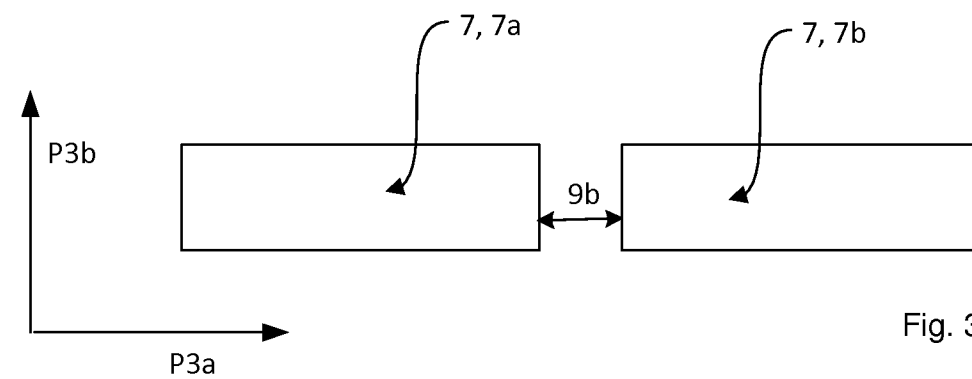
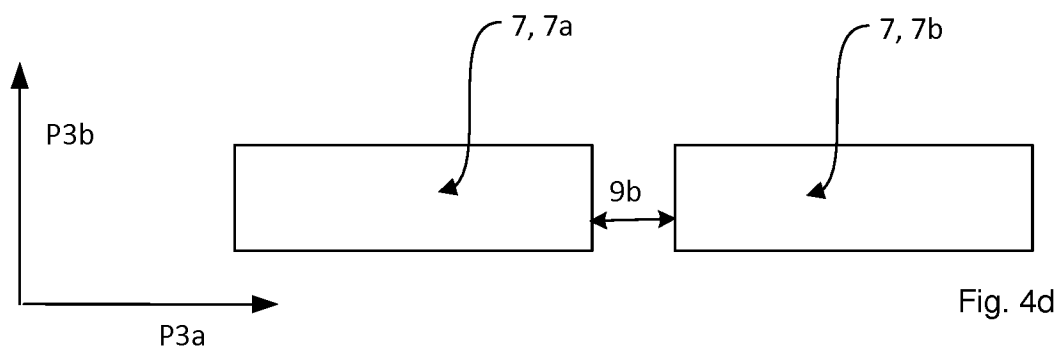
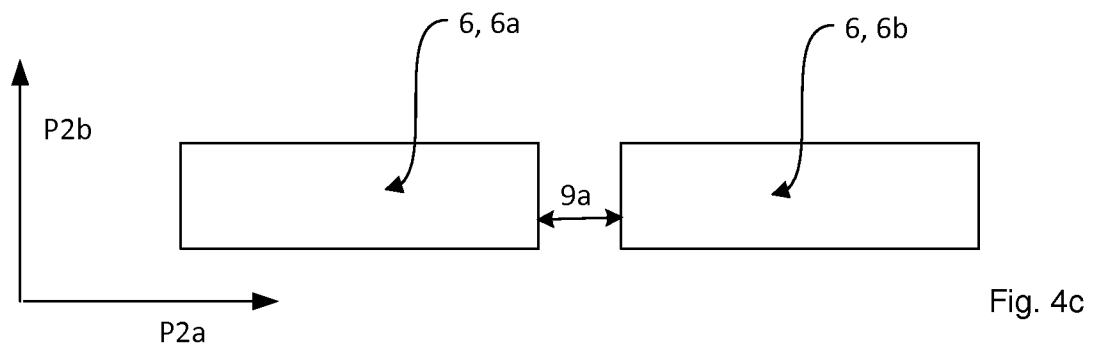
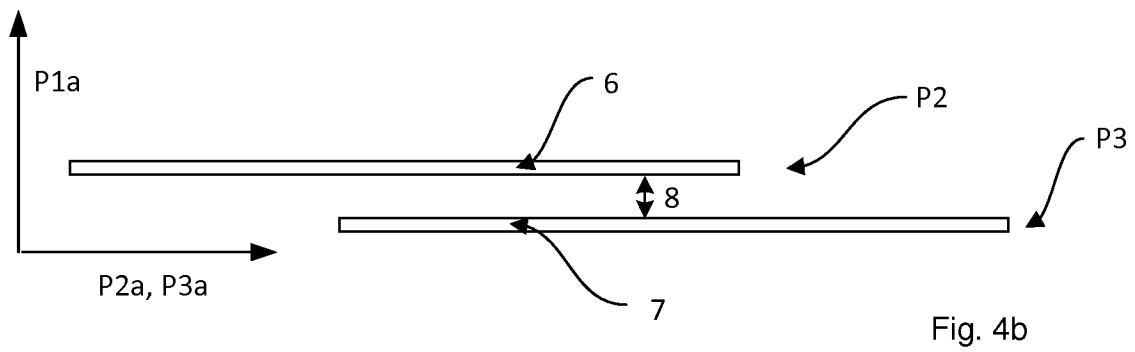
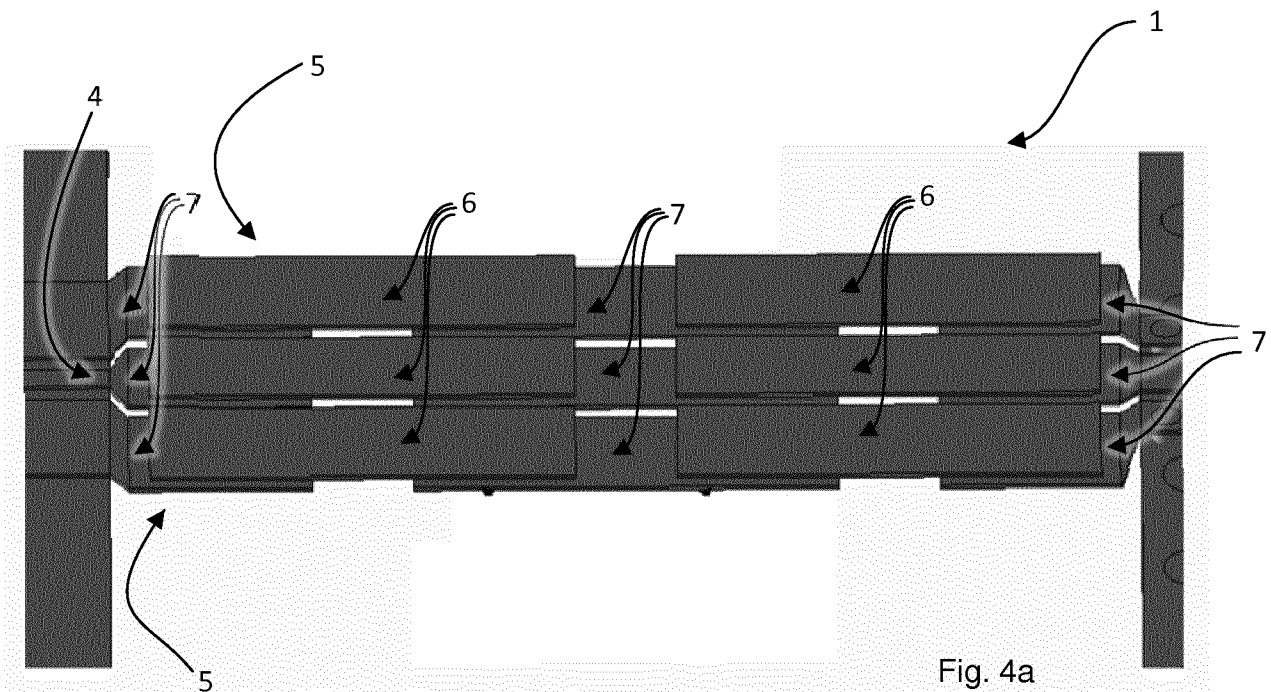


Fig. 3d

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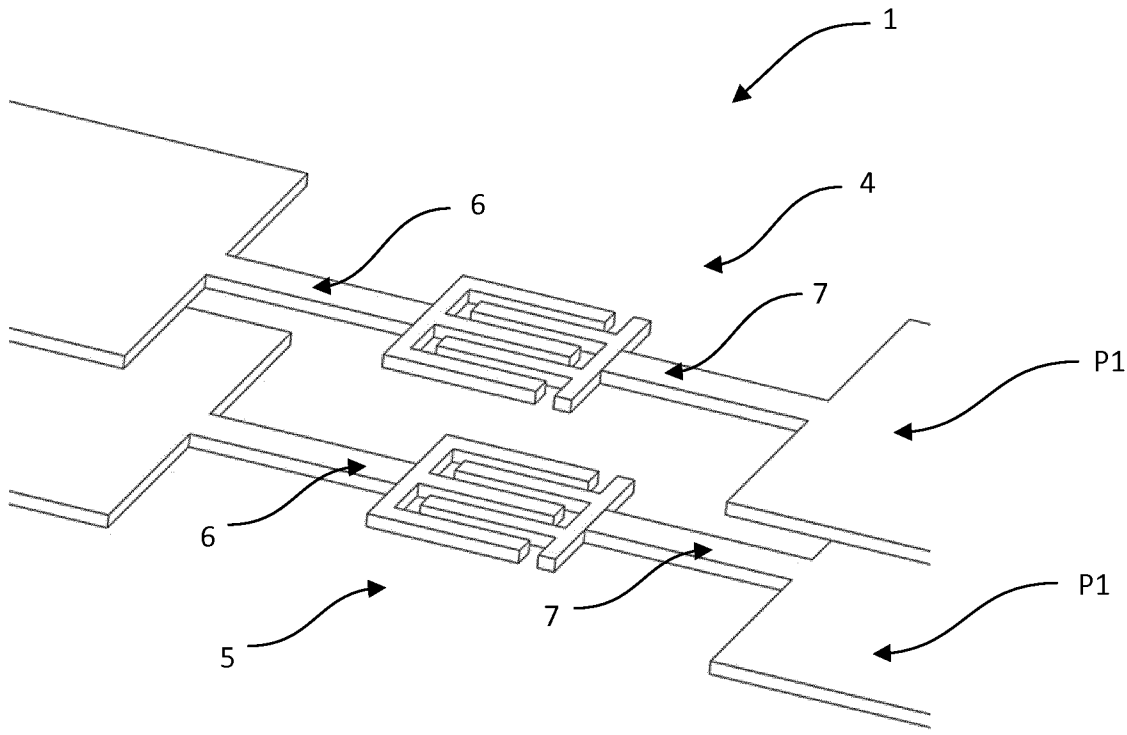


Fig. 5a

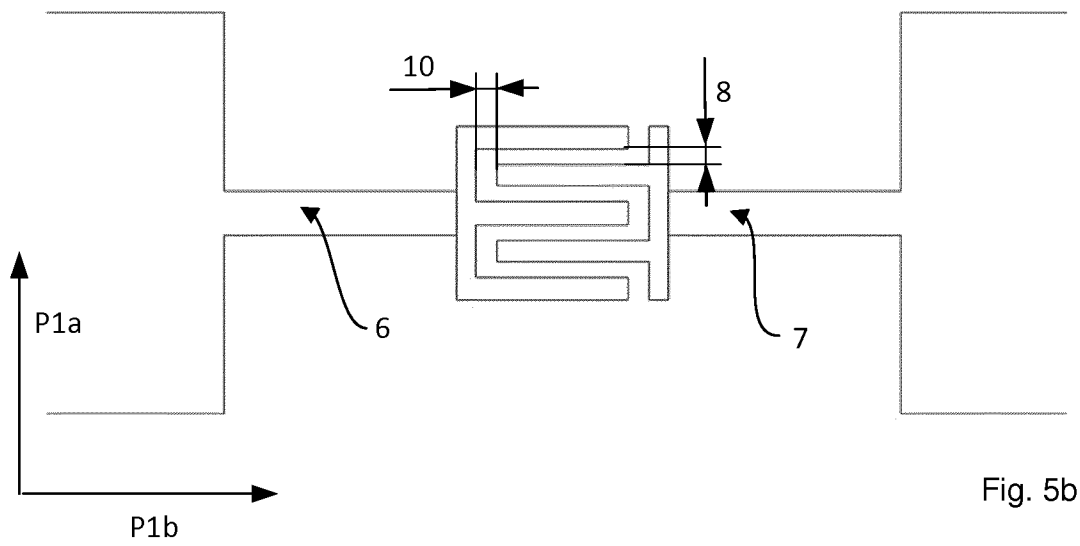


Fig. 5b

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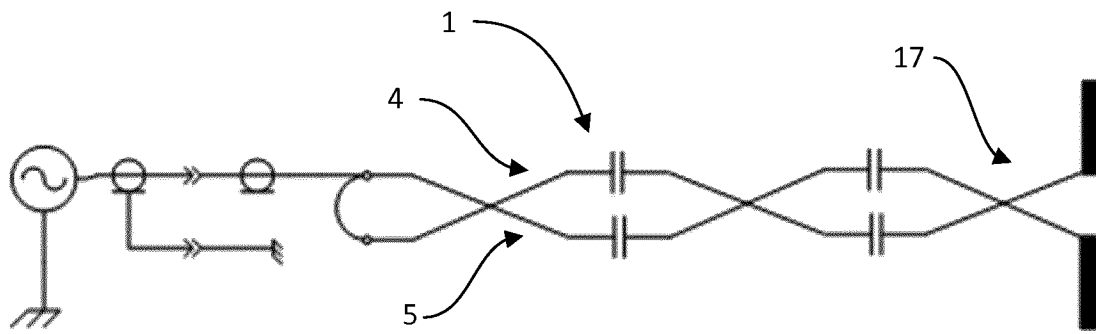


Fig. 6a

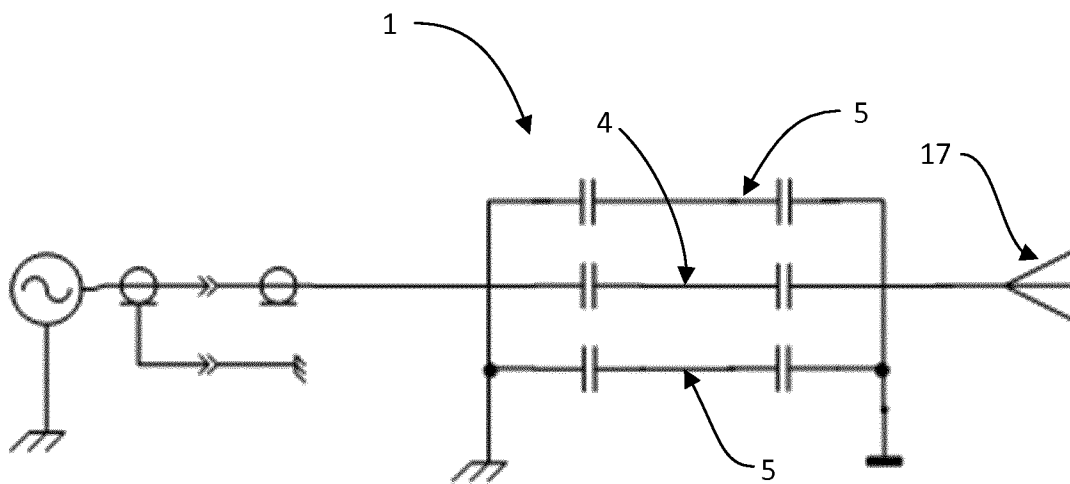


Fig. 6b

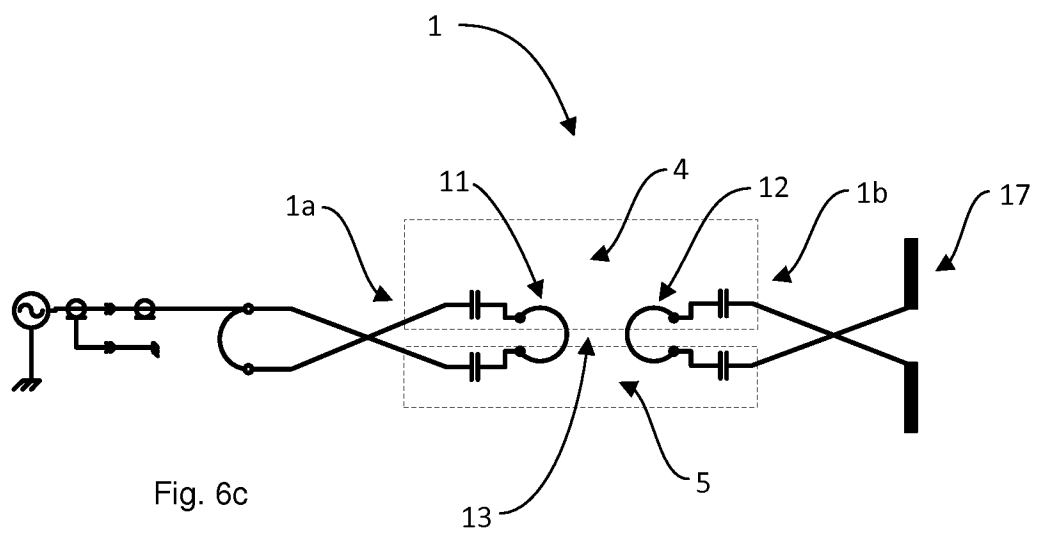


Fig. 6c

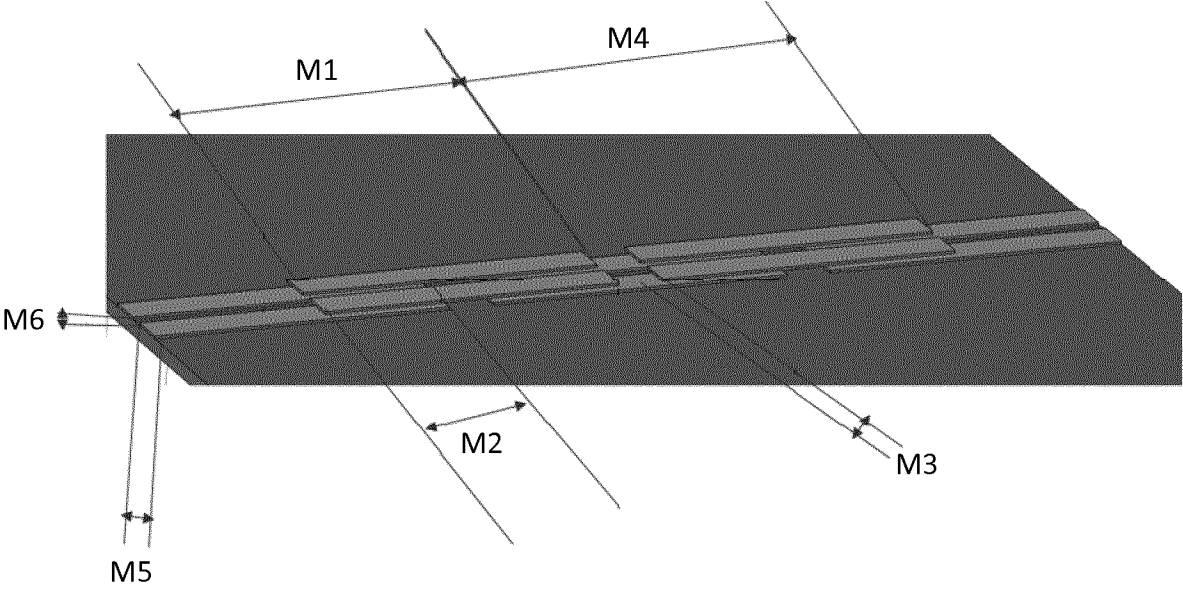


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/054536

A. CLASSIFICATION OF SUBJECT MATTER		
INV.	H01P1/203	H01P1/201
	H01Q21/28	
	H01Q1/24	H01Q1/52
		H01Q5/307
ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols)		
H01P H01Q		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
EPO-Internal		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 825 263 A (FALT CHRISTOPHER EDGAR [CA]) 20 October 1998 (1998-10-20)	1-9
Y	column 1, line 60 - column 2, line 2 column 3, lines 17-24, 47 - column 5, line 40 figures 2, 3a, 3b column 7, lines 37-59 figure 7 column 8, line 51 - column 9, line 10 figures 10a-10d column 9, lines 11-36 figures 11a-11d column 3, lines 17-24 column 10, lines 7-13 figures 13, 14a, 14b ----- -/-	11-15
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search		Date of mailing of the international search report
14 October 2019		21/10/2019
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Culhaoglu, Ali

INTERNATIONAL SEARCH REPORT

International application No
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	column 2, line 20 - column 3, line 62 figure 1	12-15
Y	----- US 5 017 897 A (OOI LENG H [US] ET AL) 21 May 1991 (1991-05-21) column 2, lines 41-51 figure 4	11
Y	----- US 2017/110787 A1 (OUYANG YUEHUI [US] ET AL) 20 April 2017 (2017-04-20) paragraph [0043] paragraphs [0049] - [0051] paragraphs [0065] - [0069] paragraph [0073] paragraph [0086] figures 3, 9, 17-19	12-15
A	----- WO 2018/206116 A1 (HUAWEI TECH CO LTD [CN]; KHRIPKOV ALEXANDER [SE]) 15 November 2018 (2018-11-15) page 8, line 14 - page 10, line 25 page 14, line 28 - page 16, line 3 figures 1a, 1b, 5, 6	1-15
A	----- CN 207 781 895 U (SHANGHAI AMPHENOL AIRWAVE COMMUNICATION ELECTRONICS CO LTD) 28 August 2018 (2018-08-28) figure 6	1-15

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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