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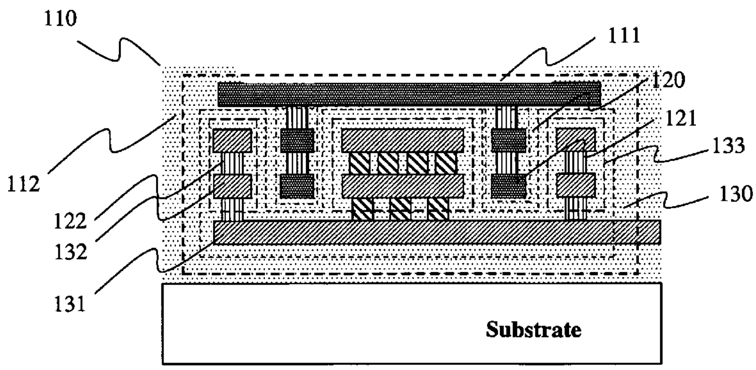

Fig. 2

(57) Abstract: The present invention in a single structure combines a pad comprising a connection terminal suitable for connecting the circuit elements integrated in a chip to circuits outside of the chip itself and at least one condenser. By combining a connection pad and a condenser in a single structure it is possible to reduce the overall area of the chip that otherwise in common integrated circuits would be greater due to the presence of the condenser itself. In this way, the costs and size of the chip can be reduced.

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CONNECTION STRUCTURE FOR AN INTEGRATED CIRCUIT WITH CAPACITIVE FUNCTION

FIELD OF THE PRESENT INVENTION

The present invention refers to a connection structure having the function of a pad including a capacitive element and suitable for being used during the testing step of electronic components in a substrate and/or as a circuit element in the final application of the integrated circuit. The present invention also refers to a system comprising a connection structure and one or more circuit elements connected to said connection structure.

STATE OF THE ART

Thanks to the progress in the field of production processes of integrated electronic circuits, the electronic components have become smaller, thus allowing the production of substrates including a large number of integrated circuits. It is also possible to produce compact electronic circuits comprising a large number of components and consequently the density of the connection terminals suitable for connecting the integrated electronic circuits has also drastically increased. The latest generation of devices thus have a large number of terminals or pad to place in contact, which have a small area and are often very close to one another.

After having been formed in the substrate called wafer, the integrated circuits must be tested so as to be able to optionally remove defective components or repair them if possible. The functionality of each integrated circuit in the substrate is checked by means of suitable probes that make contact with the connection terminals or pads of the integrated circuit itself that must be tested and that in the jargon is called DUT (Device Under Test). During the testing process an ATE (Automatic Test Equipment) or tester is electrically connected to the wafer on which the electronic components are formed. The interface between the ATE and the wafer is a probe card, comprising a PCB (printed circuit board) and a plurality of probes that electrically connect the ATE with the pads of the devices under test. In general, the wafer is arranged on a support called a chuck belonging to an apparatus called a prober.

The pads commonly used in the building of integrated circuits can have very complex and articulated mechanical structures. A structure for a pad suitable for reducing the risk of delamination and microfractures after high mechanical stresses of the assembly process is described in US 2002/0179991 A1.

Moreover, in the literature there are various known mechanical structures for pads, which have the purpose of increasing the reliability of the assembly and packaging process and of making the surface of the pad rough so as to increase the adhesion of the wirebond on the pad itself. The increasing need for electronic applications capable of withstanding increasingly high temperatures has required the introduction of new materials for the pads and for the connections between the pads and the package in order to ensure a good electrical connection. Such materials strengthen the pad itself and give it different mechanical characteristics with respect to those obtained using conventional materials like aluminium. A material used to manufacture latest-generation pad structures is for example nickel, which has a greater hardness than aluminium.

In general, the structure of the pad is designed so as to reduce its parasitic capacitance. In this way it is intended to avoid alterations of the signal received or emitted by the pad like for example loss, attenuation or distortion of the signal.

In the testing operations commonly carried out on integrated circuits or DUTs (Devices Under Test) electromagnetic interfaces are also used that allow the exchange of information between ATE and DUT through wireless communication based on electromagnetic waves. Consequently, both in the ATE and in the DUT there are suitable transmitting and receiving circuits (TxRx) connected for example to capacitive antennae that are very often condensers. The system described above is illustrated in figure 23.

For chips with high energy consumption it is necessary to also provide the power supply in a conventional manner through probes connected to the pads of the DUT. Concerning this, the upper surface of the pad 1111 is also used as armature of a condenser of the wireless communication interface that will be of the capacitive type between the pad itself and a system outside the chip. This situation is schematically illustrated in figure 24.

To check the integrated circuits, power lines can also be used, wherein a radio-frequency signal can for example be superimposed on the power supply as discussed in US 2009/0224784.

The use of condensers is of great importance in many systems like, for example, testing apparatuses and in particular testing interfaces like probe cards where the condensers are often used on the power lines.

In the system described in US 2006/0038576 two MEMS probes are capacitively coupled with a condenser arranged near to the tips of the probes. However, such a condenser is present on the probe card and not in the integrated circuit tested. Therefore, if the application for which the chip will be used requires the presence of a condenser, this will have to be added externally in a subsequent step for the final application. This solution is somewhat disadvantageous because it requires the addition of a condenser outside of the integrated circuit during the production step of the final system, which must be carried out after the chip has been tested, and this results in an end product of greater size given that the condenser is connected outside of the integrated circuit.

US 2003/0234415 describes various ways to make a condenser in an integrated circuit, how to use MIM (Metal Insulator Metal) condensers or condensers that use the fringing capacitance. An example of a condenser that uses the fringing capacitance is illustrated in figure 25a where the condenser is made with coplanar conductive interdigitated structures. Alternatively, the condenser can also be made vertically as illustrated in figure 25b, where such a condenser is made up of an upper metal layer 2510, a lower metal layer 2520 and vertical structures 2530 that extend alternatively from the upper metal layer 2510 and lower metal layer 2520 and respectively point towards the lower metal layer 2520 and upper metal layer 2510. In order to increase the capacitance of the condenser just described it is possible to use a stack of metal layers and of vertical connections (vias) that create vertical columns.

Another condenser for use in integrated circuits comprising more than two terminals is described in US 2007/0102788 and is obtained by creating spirals formed on different metallization layers.

Although the solutions in which the condenser is integrated in the chip allow a saving in cost and production time, the integrated circuits designed in this way are large in size since the condensers occupy a substantial area of the chip.

US 6476459 describes a device in which the condenser is integrated in the substrate of a chip under other structures like for example a pad. An example of such a system is schematically illustrated in figure 26 in which the condenser includes the metal layers 2604 and 2608 situated under the bond pad 2620 and surrounding a circuit (not shown).

Also in this case the condenser is built as an independent structure and, although such a solution reduces the lateral dimensions of the integrated circuit, it requires a greater vertical area to integrate the condenser. Indeed, since such a condenser is below the conventional pad it is necessary to design a chip having a greater number of metallization layers in which to create the generic condenser.

A problem of the structures described above is that the capacitive elements integrated in the chip occupy a large portion of its substrate, thus causing an increase in the size of the integrated circuit itself and in its cost.

SUMMARY OF THE INVENTION

Given the aforementioned problems with the existing technology, it would be advantageous to make an integrated circuit in which a condenser, which usually is of substantial size, can be integrated reducing as much as possible the space occupied by the condenser itself with the aim of producing a chip of small size, also reducing the manufacturing costs.

The specific approach of the present invention consists of making an integrated circuit in which the condenser is formed by exploiting structures already existing and belonging to other circuit elements. The idea of the present invention is to create a microelectronic structure that is a pad and contains at least one condenser. In particular, instead of reducing the parasitic capacitance of the pad it is enhanced in order to create at least one condenser inside the pad itself.

According to a first embodiment the present invention provides a connection structure suitable for being used in an integrated circuit comprising a plurality of metallization layers. The connection structure comprises a first metal layer suitable for being connected to one or more circuit elements outside of the integrated circuit and a conductive structure suitable for being connected to one or more circuit elements inside the integrated circuit. The conductive structure and the first metal layer are positioned so as to respectively form at least one first and a second armature of a capacitive structure.

According to this embodiment, the capacitive element is integrated in the connection structure and is made exploiting elements of the connection structure. In particular, the layer of metal in the first metallization layer has the dual function of a connection terminal and of an armature of a condenser. In this way the condenser does not have to be integrated as a self-standing structure in the chip, thus contributing to reducing the overall size of the integrated circuit. Moreover, since the condenser is made by exploiting structures belonging to other components, like a connection pad, the number of steps needed to make the circuit is reduced, contributing to simplifying and speeding up the production process, reducing the production costs.

Usually, it is attempted to reduce as much a possible the parasitic capacitance of the interconnection structures integrated in a chip so as to be able to use them without distinction for high and low frequency signals. In reality, only some interconnection structures of the chip will be used for high frequency signals, and some of them can then be connected to integrated condensers.

Therefore, this interconnection structure with a capacitive element can be advantageously used for interconnection structures where there are low frequency signals or more generally where the capacitive element does not appreciably alter the signal itself, or where there would still be a capacitive element connected to the interconnection structure through which high frequency signals also pass. Advantageously, this interconnection structure with a capacitive element can also be used to eliminate the presence of undesired high frequency signals. Moreover, where necessary, it is possible to make the capacitive element with shield structures so as to minimise its influence on the signals that pass through the interconnection structure.

BRIEF DESCRIPTION OF THE FIGURES

The attached figures are incorporated into the description and form part thereof in order to illustrate different embodiments of the present invention. The aforementioned figures together with the description are to explain the principles of the invention. The figures are provided for the sole purpose of illustrating preferred and alternative examples of how the invention can be made and used, and should not be interpreted to limit the invention to just the embodiments illustrated and described. Additional characteristics and advantages will become clear from the following and more detailed description of the different embodiments of the invention, as illustrated in the attached figures, in which the same numbers refer to the same elements.

Figure 1 is a schematic drawing illustrating a portion of an integrated circuit comprising a connection structure according to a first embodiment of the present invention;

figure 2 is a schematic drawing illustrating a longitudinal section of a connection structure used in the integrated circuit of figure 1 according to an embodiment of the present invention;

figure 3 is a schematic drawing illustrating a longitudinal section of a connection structure used in the integrated circuit of figure 1 according to a further embodiment of the present invention;

figures 4 to 12 are schematic drawings illustrating a cross section of connection structures used in the integrated circuit of the figures according to different embodiments of the present invention;

figures 13 to 22 are diagrams illustrating circuits including a connection structure according to alternative embodiments of the present invention;

figure 23 is a schematic drawing illustrating a testing system according to the state of the art;

figure 24 is a schematic drawing illustrating a system comprising a transceiver according to the state of the art;

figures 25a and 25b are a schematic drawing illustrating a condenser according to the state of the art;

figure 26 is a schematic drawing illustrating a connection pad according to the state of the art.

DETAILED DESCRIPTION OF THE INVENTION

In the following description, for explanatory purposes specific details are provided in order to allow a clear understanding of concepts of the present invention. However, it is clear that the present invention can be made without using such specific details. Moreover, well-known structures and components are only described in their general form so as to make their description easier.

The problem forming the basis of the present invention is based on the need to produce microelectronic components of increasingly small size, reducing the costs.

Moreover, the present invention is based on the observation that in integrated circuits or chips possible capacitive elements are integrated in dedicated areas of the chip and in general when designing the integrated circuit it is attempted to eliminate the parasitic capacitance in the pads so as to avoid alterations of the functionalities of the pad itself. This means that a substantial area of the integrated circuit is occupied by capacitive structures that are extremely bulky, thus setting a limit to the possibility of reducing the size of the integrated circuit.

According to the present invention, the capacitive structures are integrated in the structure of a normal connection pad used to connect circuit elements of the integrated circuit with other circuits in the integrated circuit itself or with external systems or apparatuses. In particular, a connection structure comprises, on the upper metallization layer, a connection terminal suitable for being connected to one or more circuit elements of the integrated circuit and/or to circuits and/or apparatuses outside the integrated circuit. The connection structure also comprises a conductive element on a metallization layer below the connection terminal. The metallic connection terminal and the conductive element are positioned so as to form a first and a second armature of a condenser. The conductive element can have different shapes and sizes. In the simplest embodiment of the present invention the conductive element can be a metal layer.

Figure 1 illustrates a longitudinal section of a portion of an integrated circuit or chip 100 including a connection structure with a capacitive element or CPAD 110 suitable for connecting circuit elements of the integrated circuit with circuits outside of it. The connection structure includes a first metal layer 111 that can be used as a connection pad or terminal and a conductive structure 130. The first metal layer 111 and the conductive structure 130 are arranged so as to form two armatures of a capacitive structure or condenser 112. Moreover, the connection structure 110 includes a conductive element (not shown) connected to the connection terminal itself. The conductive element can be used to connect the connection terminal 111 or pad to other circuits (not shown) present in the chip 100 that can be inside or outside the connection structure. The condenser 112 can also be in turn connected to the terminal 111 or to circuits of the chip 100 outside the connection structure 110.

The connection structure 110 can also comprise a mechanical reinforcement structure (not shown) of conductive material so as to allow it to withstand mechanical stresses due for example to the assembly process. Said mechanical reinforcement structure can be connected to the first metal layer 111 and arranged so as to increase the capacity of the capacitive structure 112.

Figure 2 illustrates a longitudinal section of the connection structure 110. The structure 110 includes at least one first metal layer 111 formed on an upper metallization layer of the connection structure 110 and that can be used as a connection terminal. The first metal layer 111 is formed with an electrically conductive material and can be selected so as to be mechanically hard. In some applications it may be preferable, for the first metal layer 111, to use a material that also has mechanical properties, like for example nickel, cobalt, their alloys or materials with mechanical and magnetic characteristics similar to those of the materials listed above. In this way, the connection pad 110 has a good resistance to mechanical stress.

The connection structure 110 of figure 2 includes a plurality of metallization layers where the first metal layer 111 occupies the upper metallization layer and can be used as a connection terminal. The connection structure 110 can also include at least one mechanical reinforcement structure 120. The mechanical reinforcement structure can be formed using metal and vias and it has the function of strengthening the connection structure 110, which is generally subjected to substantial mechanical stress due for example to the probing process and to the assembly process. The mechanical structure 120 can also at least in part have an electrical function so as to be able to conduct an electric current and thus also have a capacitive function so as to be able to be used at least in part as armature of a condenser. The various materials used to form the mechanical reinforcement structure 120 can also be formed from different layers, depending on the purpose having suitable electrical and/or mechanical characteristics. The mechanical reinforcement structure 120 can be a vertical structure 120 that extends from the first metal layer 111 towards the inside of the connection structure 110 and comprises at least one discontinuous layer of metal formed in at least one lower metallization layer situated below the first metal layer 111. The discontinuous layer of metal includes a plurality of metallic sub-structures 121 possibly interconnected by through holes or vertical interconnect accesses 122 (vias). The mechanical reinforcement structure 120 can be connected to the first metal layer 111 through at least one vertical interconnect access 122.

The metallic sub-structures 121 can have various shapes and sizes but must still be such as to ensure the correct operation of the connection structure 110, in accordance with the operating frequencies of the connection structure 110. For example, by making the connection terminal 111 with a mechanically hard material, the upper part of the connection structure 110 is strengthened so as to reduce the size of the metallic sub-structures 121. Moreover, by increasing the thickness of the connection terminal 111 it is possible to ensure greater mechanical strength of the connection structure 110.

The connection structure 110 also includes a conductive structure 130 comprising a second metal layer 131 formed in a lower metallization layer of the connection structure 110. The second metal layer 131 can be connected to one or more integrated circuits in a chip comprising the connection structure 110. The connection structure 130 also includes at least one second discontinuous layer of metal 132 connected to the second metal layer 131 through at least one vertical interconnect access 122 so as to form a vertical structure 133 that extends from the second metal layer 131 towards the inside of the connection structure 110 so as to occupy the gaps between two metallic sub-structures 121 forming the mechanical reinforcement structure 120. In this way the conductive structure 130, and the structure comprising the connection terminal 111 and the mechanical reinforcement structure 120 are interdigitated, thus constituting a first and a second armature of a condenser 112 that uses the fringing capacitance so as to increase the capacitance of the condenser 112.

Even if in the system illustrated in figure 2 the mechanical reinforcement structure 120 includes two discontinuous layers of metal formed in two different metallization layers, the mechanical reinforcement structure 120 could include an arbitrary number of discontinuous layers of metal connected together by vias 122.

Similarly, the conductive structure 130 can have different shapes according to the characteristics of the connection structure 110 and the function of the capacitive structure 112, as will be shown hereafter with reference to the other embodiments of the present invention. In particular, even if the conductive structure 130 of figure 2 includes two discontinuous layers of metal 132, the conductive structure 130 could include an arbitrary number of discontinuous layers of metal connected together by vias 122.

In other words, the conductive structure 130 comprises a second metal layer 131 in a metallization layer below the first metal layer 111 and at least one first discontinuous layer of metal 132 connected to the second metal layer 131. Moreover, the mechanical reinforcement structure 120 includes at least one second discontinuous layer of metal 121 connected to the first metal layer 111 so that the first discontinuous layer of metal and the second discontinuous layer form an interdigitated capacitive structure.

Figure 3 is a longitudinal section of an alternative configuration of the connection structure 110, and the elements of the structure of figure 3 already described with reference to figure 2 will not be described any further. In the embodiment of figure 3 the first metal layer 111 is coated by an outer metal layer 140 formed by a mechanically hard and electrically conductive material like nickel, cobalt, an alloy thereof or any other material having electrical, mechanical and magnetic properties similar to those of the materials listed above. The outer metal layer 140 further strengthens the connection structure 110. Consequently, the mechanical reinforcement structure can be reduced or, at the limit, eliminated. According to this configuration (not shown) the capacitive surfaces forming the armatures of the condenser 112 can be reduced, in such a way reducing the overall capacitance of the condenser 112 so as not to influence the behaviour of the connection structure 110. Otherwise, the mechanical structures 120 and the vertical structures 133 can be made narrower and denser to increase the overall capacitance of the condenser 112, according to the design requirements.

Figure 4 shows a horizontal section of a connection structure 210. The connection structure 210 includes a lateral mechanical structure 220 that extends along the outer perimeter of the connection structure 210. In the embodiment of figure 4 the lateral mechanical structure 220 is shaped like a crown with square section but this is not limiting for the idea of the invention, according to which the mechanical structure 220 can have a circular, elliptical, and similar section. The mechanical structure 220 is connected to the first metallic layer 111 (not visible in the figures) and each of its sides comprises a plurality of metallic plates 221 that extend towards the centre of the connection structure 210. The connection structure 210 also includes a conductive structure 230 comprising a plurality of conductive plates 231. The conductive structure is arranged inside the mechanical reinforcement structure 220 so that each of the conductive plates 231 is arranged between two metallic plates 221 of the mechanical reinforcement structure or else between a metallic plate 221 and a side of the mechanical reinforcement structure 220. In this configuration, the conductive structure forms a first armature of a condenser 212 whereas the mechanical reinforcement structure 220 forms a second armature of a condenser 212. In this embodiment both of the armatures are interdigitated so as to increase the capacitance of the condenser 212. Figure 4 shows a horizontal section of a metallization layer of the connection structure 210, however the mechanical structure 220 and the conductive structure 230 can be formed on many metallization layers according to the requirements and the function of the connection structure 210. The various layers of the mechanical and conductive structures 220 and 230 can be interconnected through vias 122 (not shown).

Although the mechanical structure 220 includes a plurality of metallic plates 221 on every side, it is possible to have a mechanical structure having metallic plates 221 only on some of its sides.

In figure 5 the mechanical reinforcement structure 220 includes a plurality of metallic plates 221 that extend from one side of the mechanical structure 220 towards the inside of the connection structure 210. The elements of figure 5 already described with reference to figure 4, like for example the conductive structure 230, will not be described any further.

In order to increase the capacitance of the condenser 212, the metallic plates 221 and the conductive plates 231 can include sub-structures in the form of protuberances 222 and 232 that extend perpendicular to the surface of the metallic and conductive plates 221 and 231. The mechanical structure 220 and the conductive structure 230 can be arranged so that the metallic and conductive plates 221 and 231 and the protuberances 222 and 232 are interdigitated. Such a structure is illustrated in figure 6.

Figure 7 shows a connection structure 210 where the mechanical structure 220 includes a plurality of metallic plates 221 on two opposite sides and extending towards the inside of the connection structure 210. In this embodiment the conductive structure 230 that defines the first armature of the condenser 112 is coil-shaped.

Figure 8 shows a connection structure 310 in which a mechanical reinforcement structure 320 includes a plurality of metallic plates 321 connected so as to form a coil. The connection structure 310 also includes a conductive structure 330 shaped like a coil and positioned inside the connection structure 310 so that every conductive plate 331 forming the conductive structure 330 is positioned between two metallic plates 321 forming the coil of the mechanical structure 320.

Figure 9 shows a connection structure 410 comprising a lateral mechanical structure 420 that extends along the outer perimeter of the connection structure 410. The mechanical structure 420 is connected to the first metallic layer 111 (not visible in the figures). The connection structure 410 also comprises a first and a second conductive structure 430 and 440 shaped like a crown with a square section. The perimeter of the conductive structures 430 and 440 is such that such structures can be positioned inside the mechanical structure 420 so as to form the armatures of a coaxial condenser with three armatures 412.

In the embodiment of figure 9 the lateral mechanical structure 420 and the conductive structures 430 and 440 are shaped like a crown with square section but this is not limiting for the idea of the invention, according to which such structures can have a circular, elliptical, and similar section. Moreover, although in the embodiment of figure 9 the conductive structures 430 and 440 are inside the mechanical structure 430, in other advantageous embodiments one or both of the conductive structures 430 and 440 can be larger than the mechanical structure 420 and be positioned outside of it.

According to advantageous embodiments of the present invention, it is also possible to create armatures outside of the mechanical structure of the pad. In this case there is a condenser with three armatures, one of which consists of part of the mechanical structure of the pad itself.

Figure 10 shows the embodiment described above. A connection structure 510 comprises a lateral mechanical structure 520 that extends along the outer perimeter of the connection structure 510. The mechanical structure 520 is connected to the first metallic layer 111 (not visible in the figures). The connection structure 510 also comprises a first and a second conductive structure 530 and 540 formed outside of the mechanical structure 520 and respectively arranged in front of two opposite sides of the mechanical structure 520. The first and the second conductive structure 530 and 540 and the mechanical structure 520 form three armatures of a condenser 512. In order to increase the capacitance of the condenser 512, the conductive structures 530 and 540 and at least the sides of the mechanical structure 520 in front of the conductive structures 530 and 540 can comprise protuberances 550 arranged so that the first conductive structure 530 and at least one part of the mechanical structure 520, and the second conductive structure 540 and at least one part of the mechanical structure 520 are interdigitated.

The structures 530 and 540 can be connected together in series to form a single condenser, or else they can be connected to two different circuits.

In an advantageous embodiment of the present invention an armature of the condenser can be divided into many parts that can be surrounded by another armature that can consist of at least one part of the mechanical structure of the pad.

Figure 11 shows a connection structure 610 comprising a mechanical structure 620 having a grid section. The connection structure 610 includes a plurality of vertical conductive structures 630 positioned inside the mechanical lattice structure 620 so that every vertical conductive structure 630 is surrounded by at least one part of the mechanical structure 620.

The vertical structures 630 can comprise a plurality of discontinuous layers of metal formed in different metallization layers and interconnected through vias (not shown). The vertical structures 630 can also be connected to layer of metal (not shown) formed in the lowest metallization layer of the connection structure and through this to one or more integrated circuits in a chip comprising the connection structure 610.

In general, the conductive structure can comprise a second metal layer in a metallization layer below the first metal layer or connection terminal and at least one first discontinuous layer of metal connected to the second metal layer, and the mechanical reinforcement structure includes at least one second discontinuous layer of metal connected to the first metal layer and surrounding the conductive structure.

In an advantageous embodiment of the present invention it is possible to have more than one condenser inside the connection structure.

Figure 12 shows a connection structure 710 comprising a lateral mechanical structure 720 that extends along the outer perimeter of the connection structure 710. Inside the mechanical structure 720, the connection structure comprises a first condenser 701 having armatures coaxial to one another; a second condenser 702 having a central armature that faces onto two lateral armatures in series with one another; a third condenser 703 and a fourth condenser 704 having a central armature that faces onto two lateral armatures in series with one another and having a section that allow the fringing capacitance to be exploited.

Although both of the condensers 703 and 704 are similar in operation, the fourth condenser 704 uses the fringing capacitance better thanks to two lateral protuberances 705 included in the lateral armatures of the fourth condenser 704.

The four condensers from 701 to 704 are separated and insulated from one another by plates 721 included in the mechanical structure 720 and optionally the plates 721 can be arranged at a suitable potential that can also be different from the potential of the mechanical structure 720.

Of course, the connection structure 710 can have more than four condensers and their shape and structure is not limited to those described earlier but can vary within the state of the art according to the requirements and the use of the connection structure 710.

Moreover, the connection structures from 110 to 710 can have different sections, like for example: circular, elliptical, polygonal, square, rectangular, hexagonal, octagonal and similar.

In advantageous embodiments of the present invention, the condenser and the connection terminal 111 included in the connection structures from 110 to 710 can be connected with other circuits inside an integrated circuit as well as being connected together.

In a first system described schematically in figure 13 the condenser 112-612, 701-704 is connected to the connection terminal 111 and can be part of a filter. Such a filter can, for example, have the function of eliminating the continuous component of a signal present on the connection terminal 111 or of a signal coming from a circuit 810.

Moreover, such a system can also be used to make a communication interface through a power line in which a circuit 820 is fed through the power line, whereas the circuit 810 forms a transceiver system. In particular the circuit 810 can be a transmitter, a receiver, or a transceiver/transponder.

In a variant of this circuit, shown in figure 14, the condenser 112-612, 701-704 can be connected to earth becoming a filter condenser for the power supply. Such a configuration is particularly advantageous in the checking step of an integrated circuit. Indeed, since the filter condenser is already present in the connection structure integrated in the chip to be tested, the filter condensers that are commonly formed on the printed circuit board (PCB) of the probe card and connected to a power supply probe can have a lower capacitance value or at the limit be eliminated, in this way simplifying the probe card.

Moreover, since the condenser is formed inside active connection structure 110-710, such a condenser can advantageously also be used in the final application, reducing the production costs of the chip and the size of the end product.

Figure 15 is a diagram illustrating a system comprising a connection structure 110-710 and a first and a second condenser 112-612, 701-704. The system also includes a first circuit 810, which can be a receiver connected to the connection terminal 111 through the first condenser 112-612, 701-704 and a circuit 830, that can be a transceiver, to the connection terminal 111 through the second condenser 112-612, 701-704. The system also includes a circuit 820, which can be fed through a power line.

Figure 16 is a diagram illustrating a system comprising a connection structure 110-710 and a condenser 112-612, 701-704 not connected to the connection terminal 111. In this embodiment the condenser 112-612, 701-704 can be used as a conventional condenser for a circuit 810. Given that the condenser 112-612, 701-704 is made in the area occupied by the CPAD 110-710, the area of the chip occupied by the circuit can be reduced, in this way contributing to reducing the overall size of the integrated circuit.

Advantageously, in order to avoid the condenser appreciably altering the signal of the pad it is possible for example to use a condenser with two coaxial armatures. It is also possible to use one or more shield structures, like for example a further coaxial armature that surrounds the outside of the condenser, which can be placed at a suitable reference potential thus creating an electromagnetic shield.

These solutions can advantageously be implemented, according to the design needs, in each of the connection structures described earlier.

Advantageously, the structure of the shield can have cavities in order to reduce the surface that faces onto the other structures of the CPAD, thus reducing the capacitive coupling and the parasitic capacitance.

Moreover, if necessary, it is advantageously possible to connect together, in various ways, the condensers contained in many CPADs to make condensers having large capacities.

Figure 17 is a diagram illustrating a system comprising a connection structure 110-710 and a condenser with three terminals 412, 512, 702-704 forming part of an EMI (ElectroMagnetic Interference) filter to reduce and at the limit eliminate the electromagnetic interference on a second circuit 820. In the system of figure 17 a first and a second circuit 810 and 820 are connected to the connection terminal 111 through the condenser with three terminals 412, 512, 702-704.

The circuit 810 can form part of the EMI filter, or else it can be a further circuit used for example to recover the energy of the electromagnetic disturbances to be stored or use it for example to feed at least part of the integrated circuit 100.

Therefore, the circuit 810 can perform the function of an Energy Harvester or Energy Scavenger, where by Energy Harvesting we refer to fields in which the energy source is well known, characterised and regular, whereas Energy Scavenging refers to fields in which the energy source is unknown and highly irregular.

Figure 18 is a diagram illustrating a system comprising a connection structure 110-710 and a condenser with three terminals 412, 512, 702-704. In this embodiment the armature of the condenser 412, 512, 702-704 is connected to earth, and a circuit 820 is connected to the connection terminal 111 through the condenser 412, 512, 702-704. Finally, the connection terminal 111 can be connected to a power or signal line.

Figure 19 is a diagram illustrating a system comprising a connection structure 110-

710 and a condenser with three terminals 412, 512, 702-704. In this embodiment a first circuit 810 and a second circuit 830 are connected to the connection terminal through distinct armatures of the condenser with three terminals 412, 512, 702-704.

Figure 20 is a diagram illustrating a system comprising a connection structure 110-710 with a condenser with three terminals 412, 512, 702-704. In this system the pad can be connected to earth, and this can be used for example as a filtering circuit for alternating current power supplies.

Figure 21 is a diagram illustrating a chip 100 comprising a first connection structure 110-710 or CPAD with a first condenser 112-612, 701-704 and a second connection structure 110'-710' or CPAD with a second condenser 112'-612', 701'-704'. In this system the first and the second CPAD are connected so that the first and the second condenser are connected in parallel to one another. In this way it is possible to increase the overall capacitance to allow an antenna 850 outside the chip 100 to resonate at a very precise frequency. The antenna 850 is connected to the chip through the first and the second connection terminal 111 and 111'. The connection structures 110-710 and 110'-710' are connected to a circuit 810 integrated in the chip 100 that can be a transmitter, a receiver or a transceiver/transponder.

The external antenna 850 can be connected to the CPADs 110-710 and 110'-710' using bumps or wirebonds.

Although in the circuit of figure 21 the condensers 112-612, 701-704 and 112'-612', 701'-704' are connected in parallel, this configuration is not limiting and it should be understood that the condensers can also be connected in series according to the design requirements.

In an advantageous embodiment, shown in figure 22, the antenna 850 can also be inside the chip 100, and the condensers 112-612, 701-704 and 112'-612', 701'-

704' can also have different capacitance values, and advantageously there can be electronic switches 860, which can be made for example through at least one transistor MOS or similar. Through said electronic switches it is possible to connect or disconnect at least one of the condensers 112-612, 701-704 and 112'-612', 701'-704' in this way varying the resonance frequency of the antenna.

Since the antenna 850 is connected to an active connection structure, such an antenna 850 can be used both to check the chip 100 and for the final application.

Of course, it is possible to make hybrid structures and systems with respect to the embodiments presented and in combination with the prior art.

In the connection structure 110 described with reference to figures 1 to 12 the condenser 112 is integrated inside the structure itself but in some advantageous embodiments of the present invention the condenser 112 can be in part inside and/or outside of the mechanical structure of the connection pad 110.

The at least one condenser and the connection terminal 111 can have connections with other circuits inside the integrated circuit as well as being connected together according to the purpose and the use of the connection structure.

The various parts can also be electrically insulated from one another, for example using insulating materials like oxides or dielectric materials. Such dielectric materials can also be present optionally between the at least two armatures of a condenser 112-612, 701-704 to increase its capacitance possibly reducing its size and therefore its impact on the operation of the connection structure 110-710 or CPAD.

Of course, in order to satisfy contingent and specific requirements, a man skilled in the art can bring many modifications to the solutions described earlier. Although the present invention has been described with reference to its preferred embodiments, it should be clear that various omissions, replacements and modifications in the shape and in the details, just like other even hybrid embodiments are possible also in combination with the prior art; it should be expressly understood that specific elements and/or method steps described in relation to any embodiment of the invention described can be incorporated in any other embodiment in combination with the prior art as general aspects of design choices.

CLAIMS

1. A connection structure suitable for being used in an integrated circuit comprising a plurality of metallization layers, said connection structure comprising:

a first metal layer suitable for being connected to one or more circuit elements outside of the integrated circuit; and

a conductive structure suitable for being connected to one or more circuit elements inside the integrated circuit,

wherein the conductive structure and the first metal layer are positioned so as to respectively form at least one first and a second armature of a capacitive structure.

2. The connection structure according to claim 1, also comprising a mechanical reinforcement structure made from conductive material, said mechanical reinforcement structure being connected to the first metal layer and arranged so as to increase the capacitance of the capacitive structure.

3. The connection structure according to claim 2, wherein:

the conductive structure comprises a second metal layer in a metallization layer beneath the first metal layer and at least one first discontinuous layer of metal connected to the second metal layer, wherein

the mechanical reinforcement structure includes at least one second discontinuous layer of metal connected to the first metal layer, said first discontinuous layer of metal and second discontinuous layer of metal being arranged so as to form an interdigitated capacitive structure.

4. The connection structure according to claim

the conductive structure comprises a second metal layer in a metallization layer beneath the first metal layer and at least one first discontinuous layer of metal connected to the second metal layer, and

the mechanical reinforcement structure includes at least one second discontinuous layer of metal connected to the first metal layer and surrounding the conductive structure.

5. The connection structure according to claim 2, wherein:

the mechanical reinforcement structure at least partially extends along the perimeter of the connection structure and includes a plurality of plates extending inside the connection structure; and

the conductive structure includes a plurality of conductive plates arranged inside the mechanical structure so as to form an interdigitated capacitive structure.

6. The connection structure according to claim 2, wherein the conductive structure extends outside of the mechanical reinforcement structure, said connection structure also comprising:

a third armature outside of the mechanical reinforcement structure, said conductive structure, mechanical reinforcement structure and third armature being positioned so as to form a capacitive structure with three armatures.

7. The connection structure according to claim 2, wherein the mechanical reinforcement structure extends along the perimeter of the connection structure, said connection structure also comprising:

a third armature arranged inside the mechanical reinforcement structure, wherein

the mechanical reinforcement structure, the conductive structure and the third armature form a coaxial capacitive structure with three armatures.

8. The connection structure according to claim 2, wherein:

the mechanical reinforcement structure at least partially extends along the perimeter of the connection structure and includes a plurality of plates extending inside the connection structure; and

the conductive structure includes a coil arranged between the plates of the mechanical connection structure.

9. The connection structure according to each of claims 1 to 8, also comprising at least one second capacitive structure.

10. An integrated circuit comprising a connection structure according to each of claims 1 to 9.

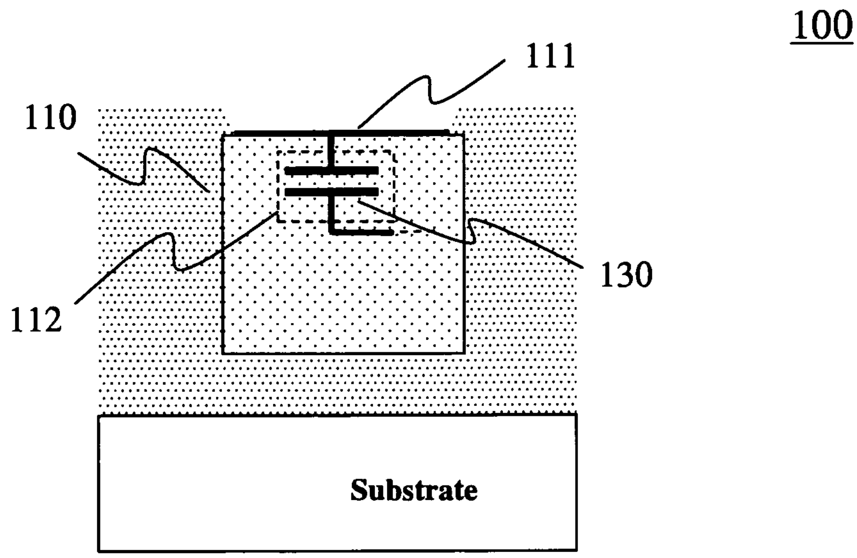
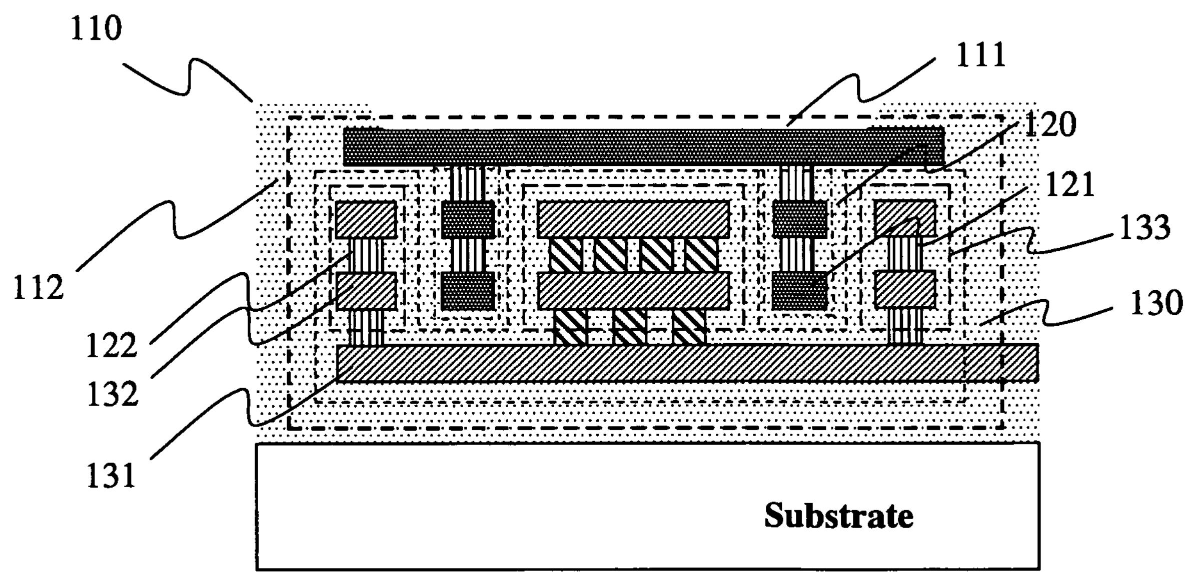

100
111
110
130
112
Substrate

Fig. 1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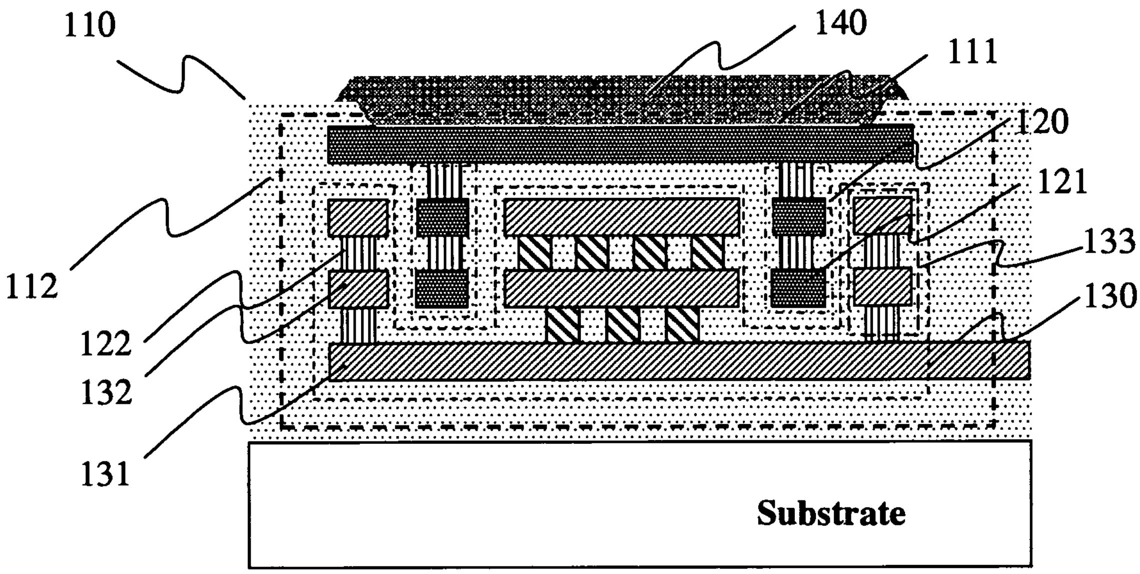
111
120
121
133
112
130
122
132
131
Substrate

Fig. 2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121
133
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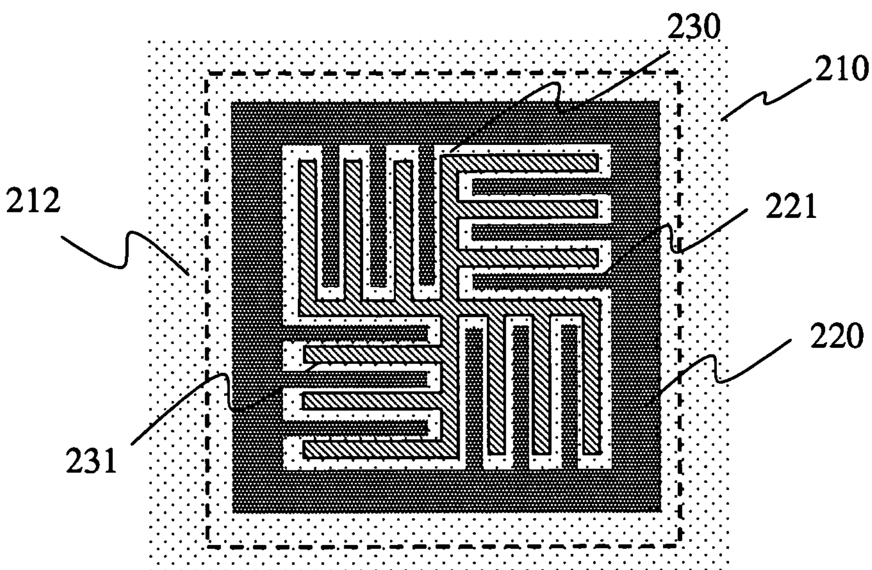
112
122
132
131
Substrate

Fig. 3


230
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221
220
231

Fig. 4

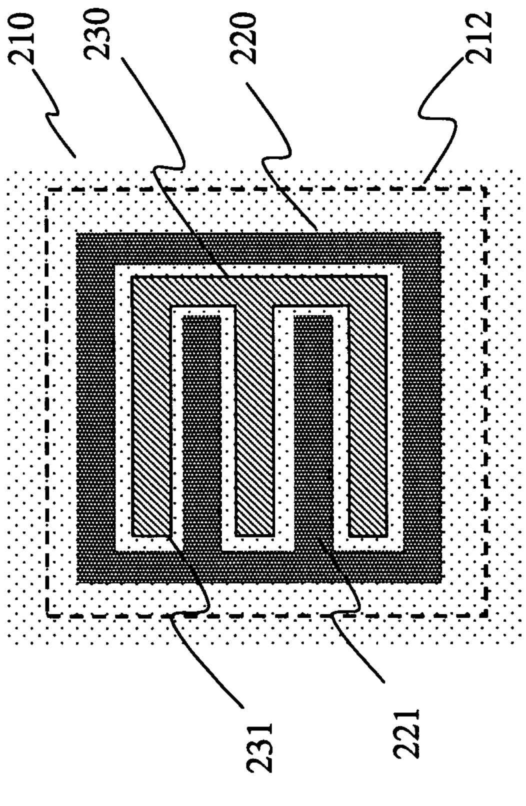


Fig. 5

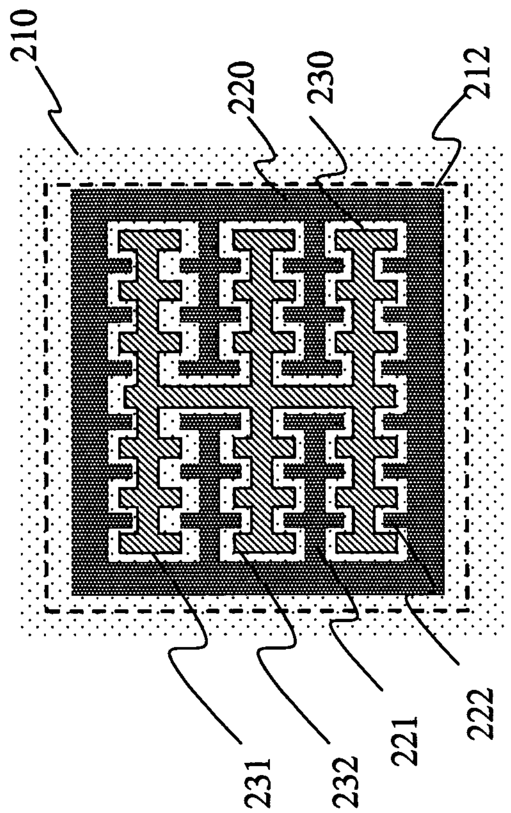


Fig. 6

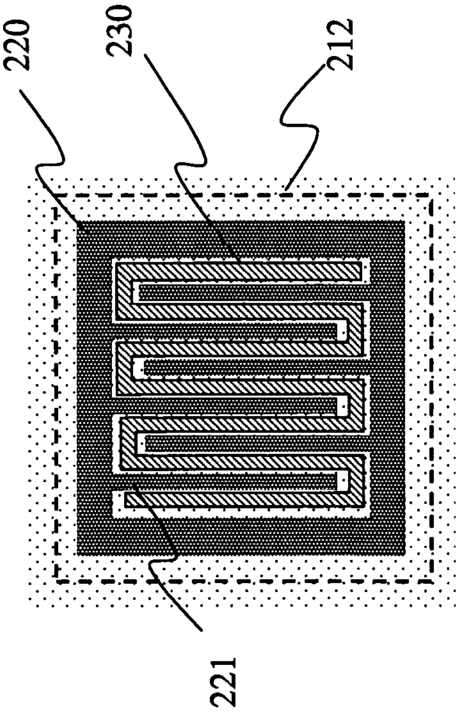


Fig. 7

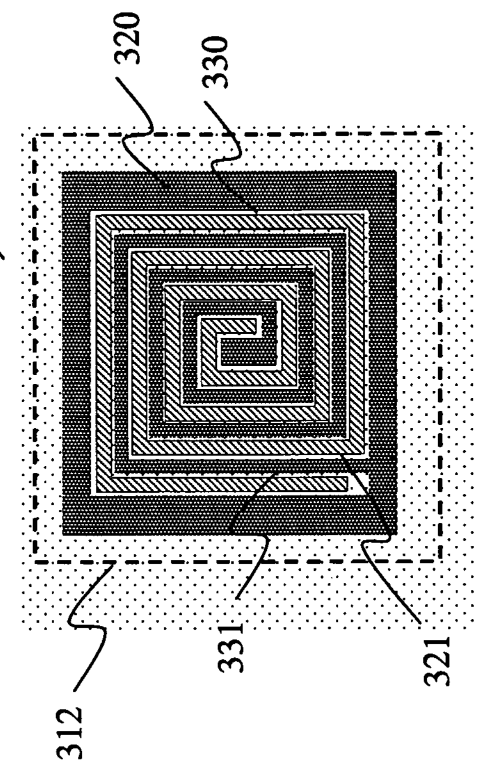


Fig. 8

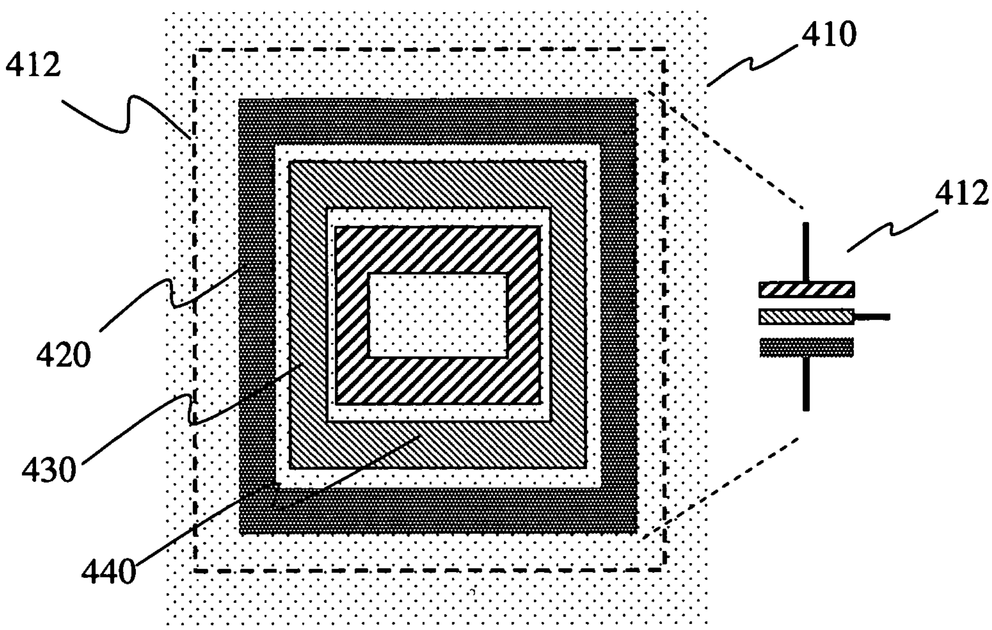


Fig. 9

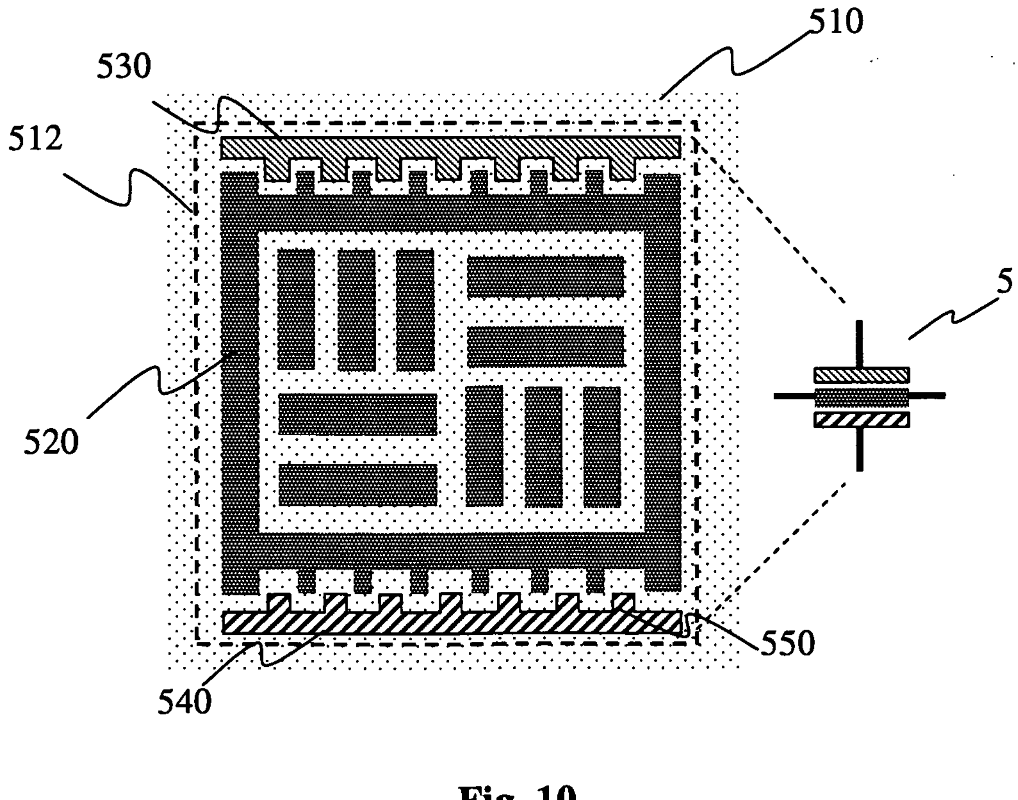


Fig. 10

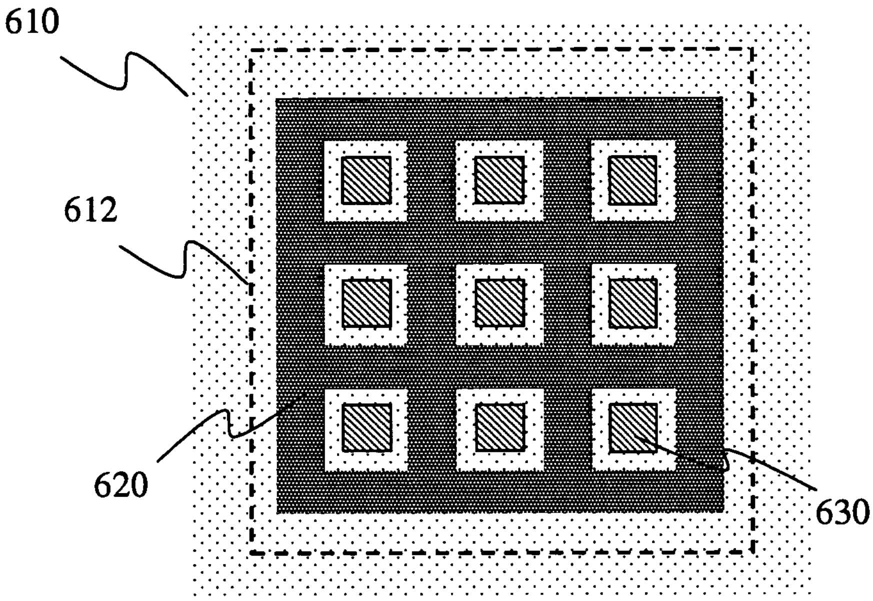


Fig. 11

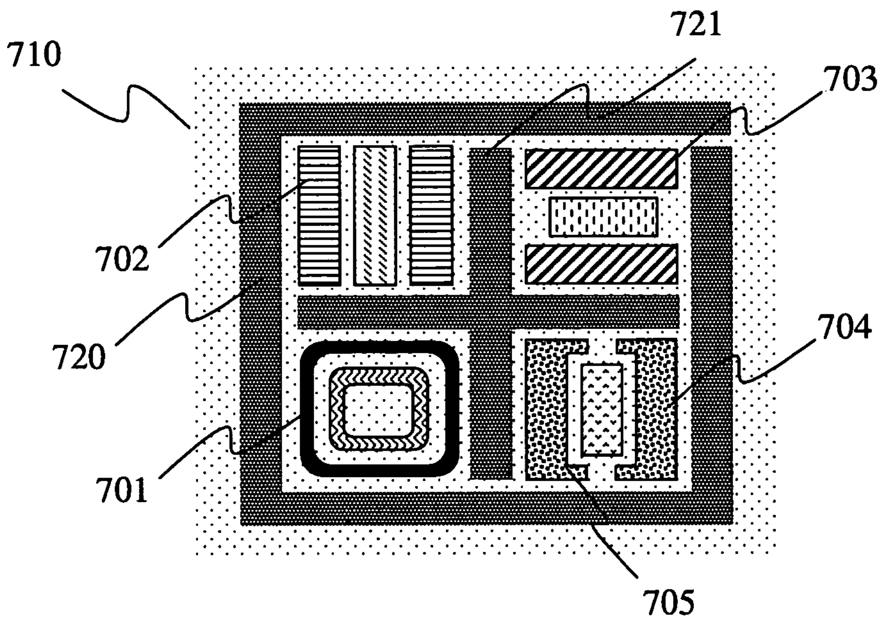


Fig. 12

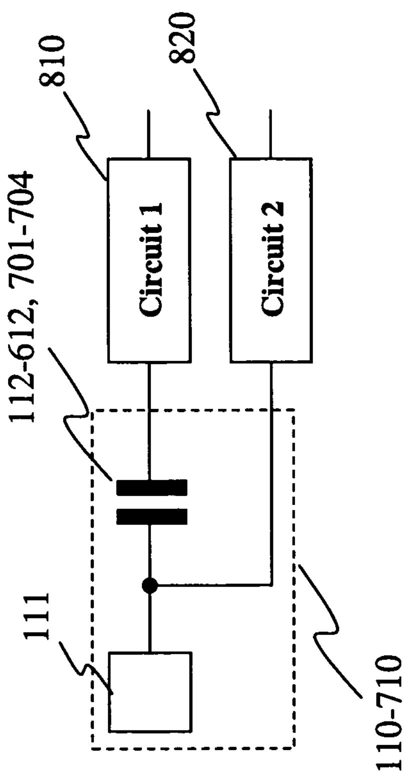


Fig. 13

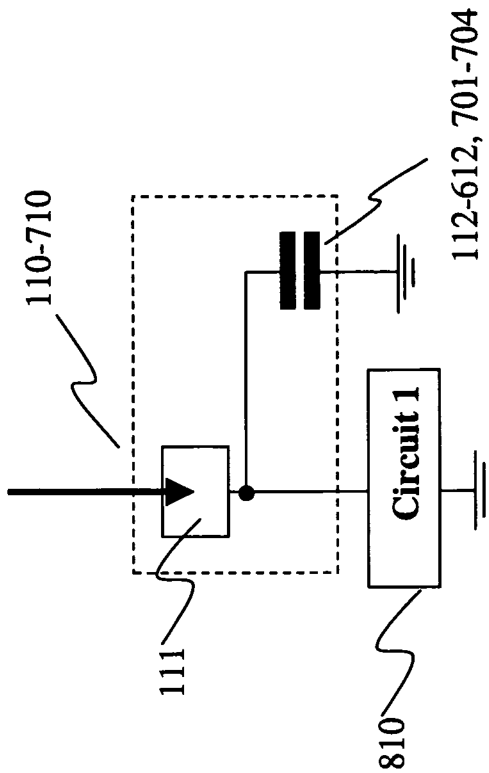


Fig. 14

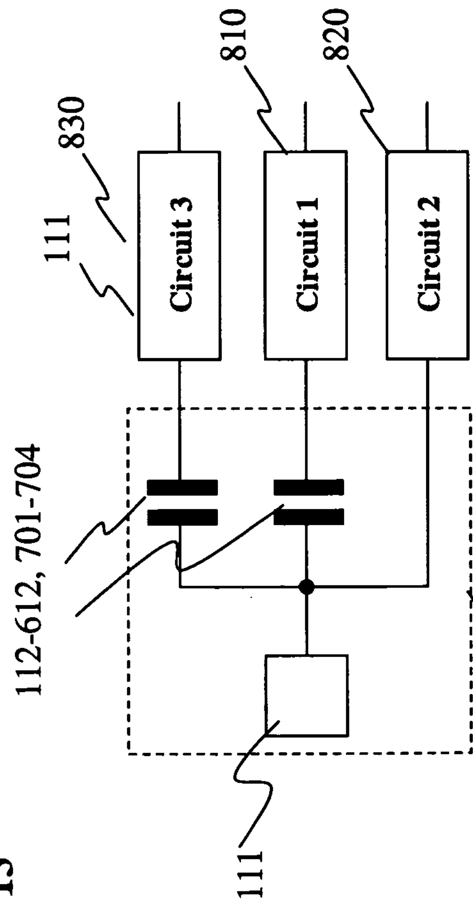


Fig. 15

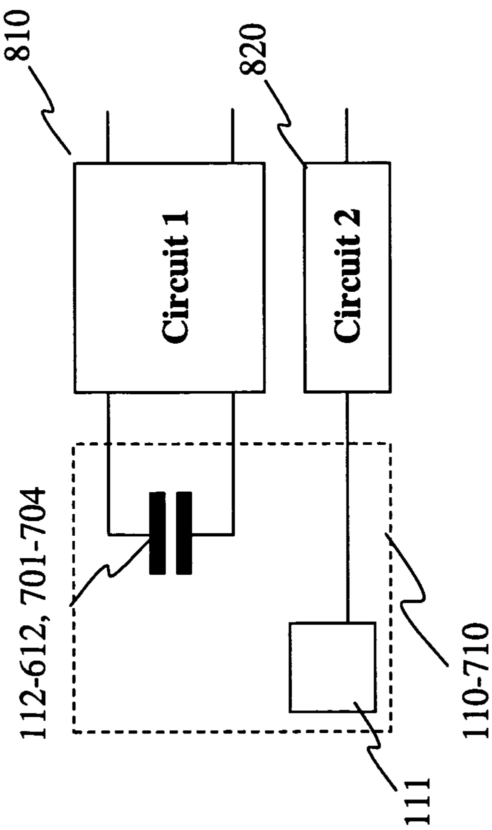


Fig. 16

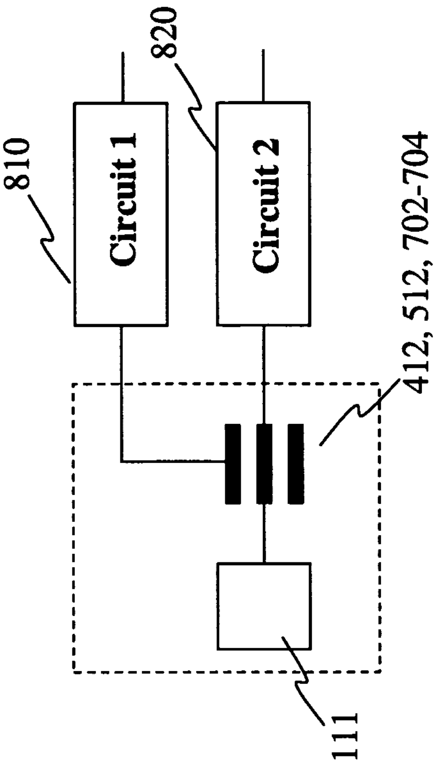


Fig. 17

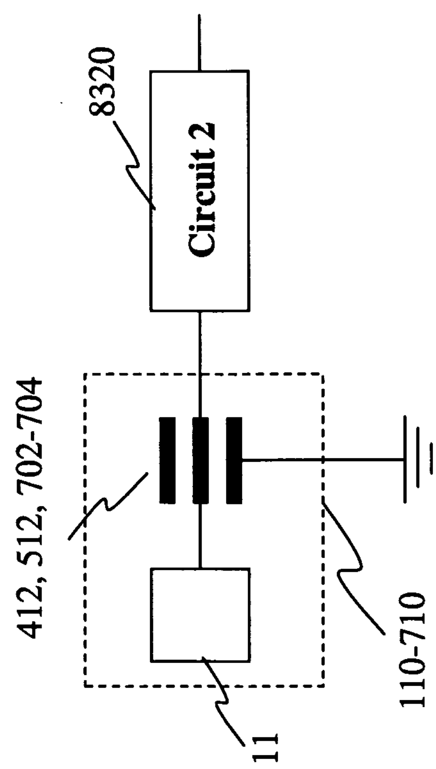


Fig. 18

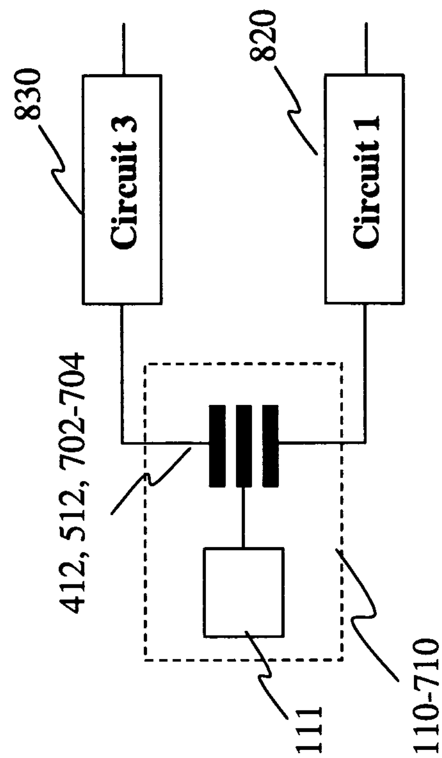


Fig. 19

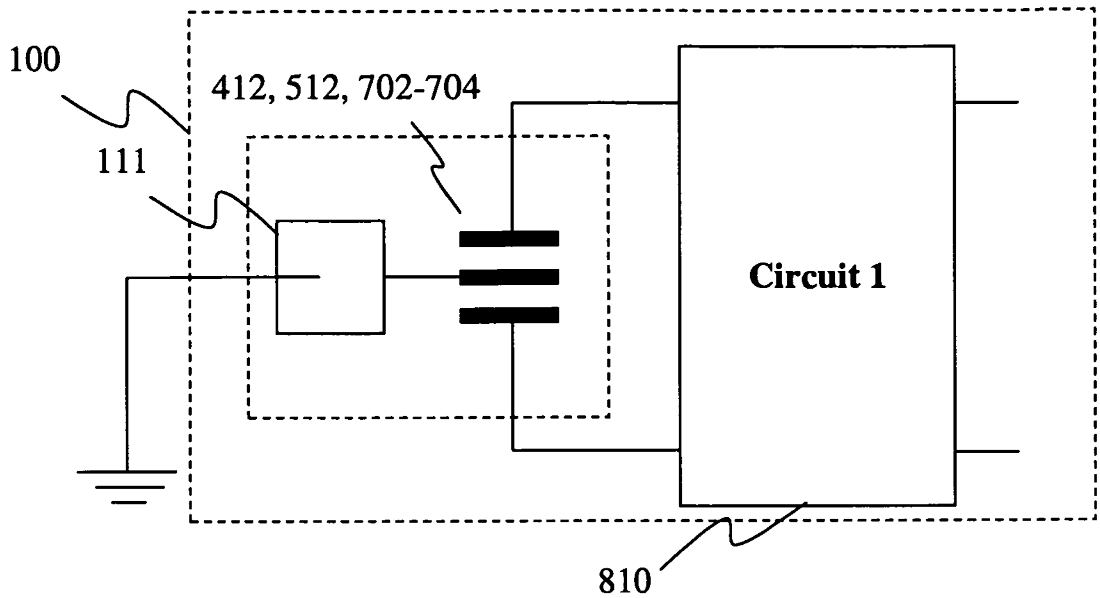

100
412, 512, 702-704
111
Circuit 1
810

Fig. 20

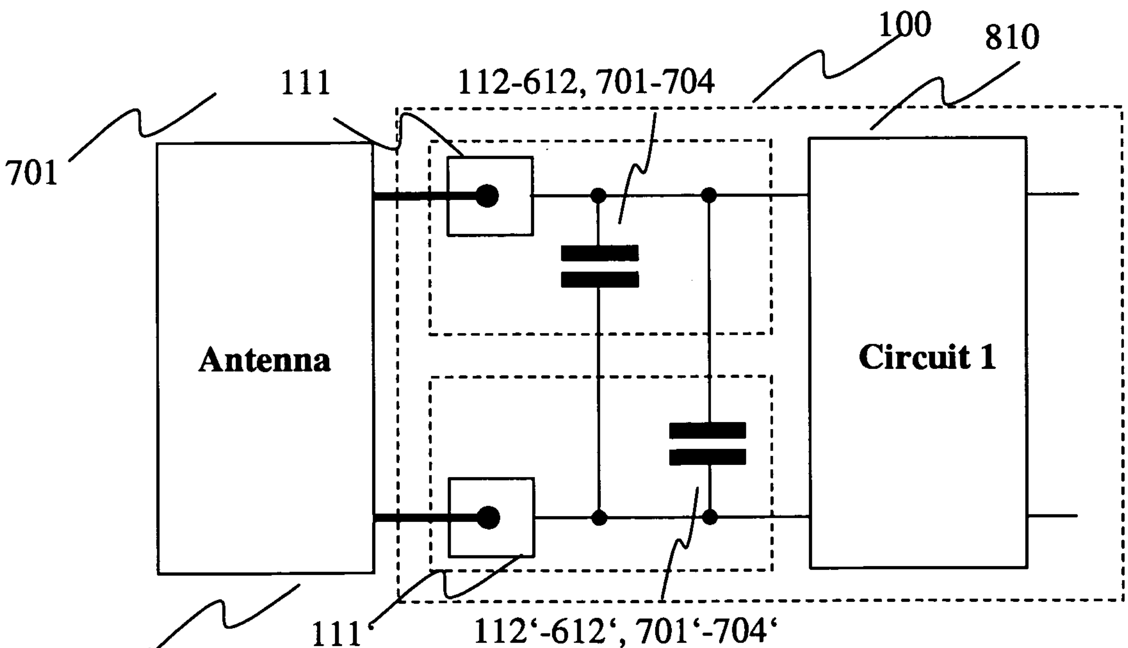
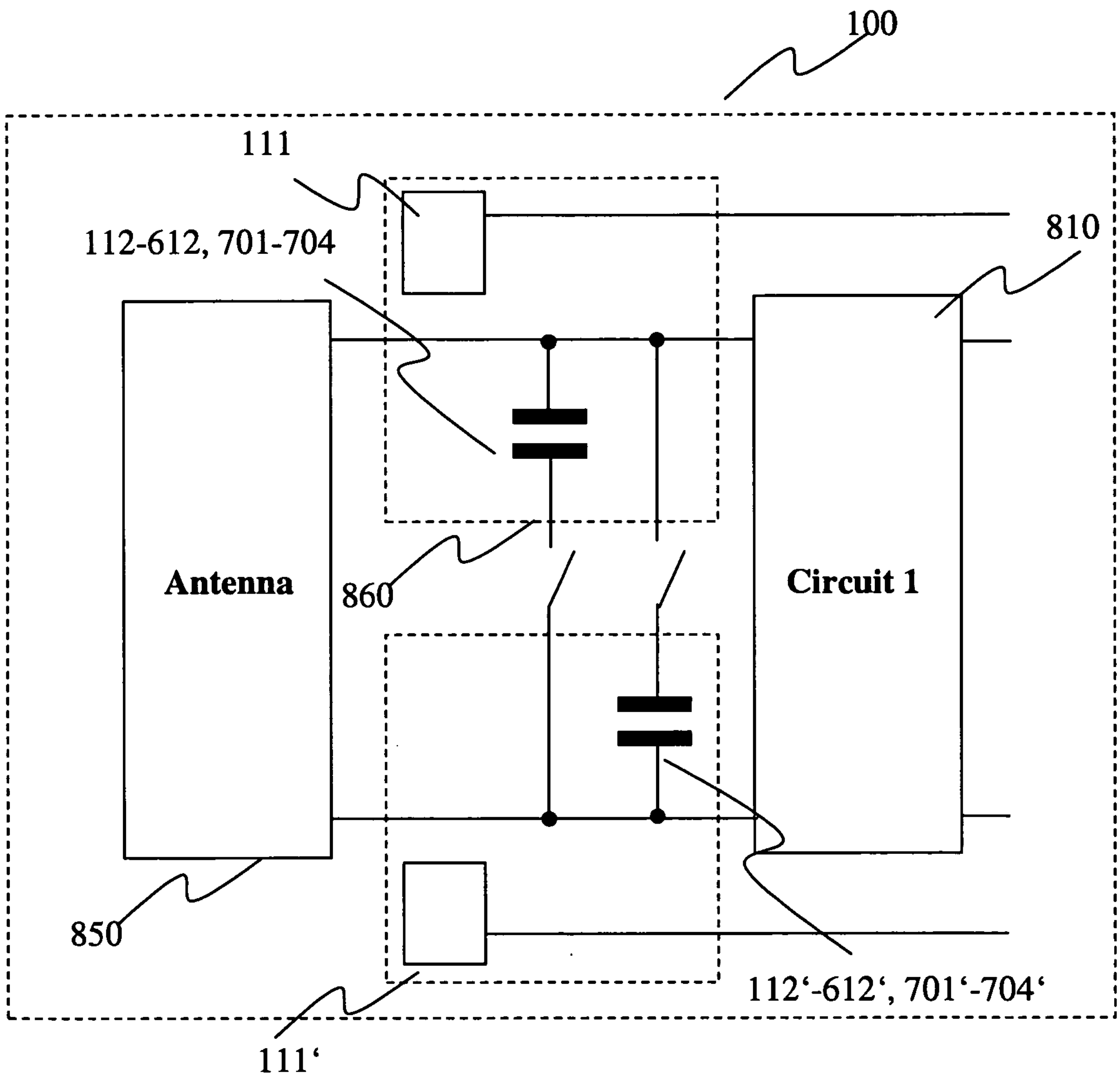

100
810
111
112-612, 701-704
701
Antenna
Circuit 1
850
111'
112'-612', 701'-704'

Fig. 21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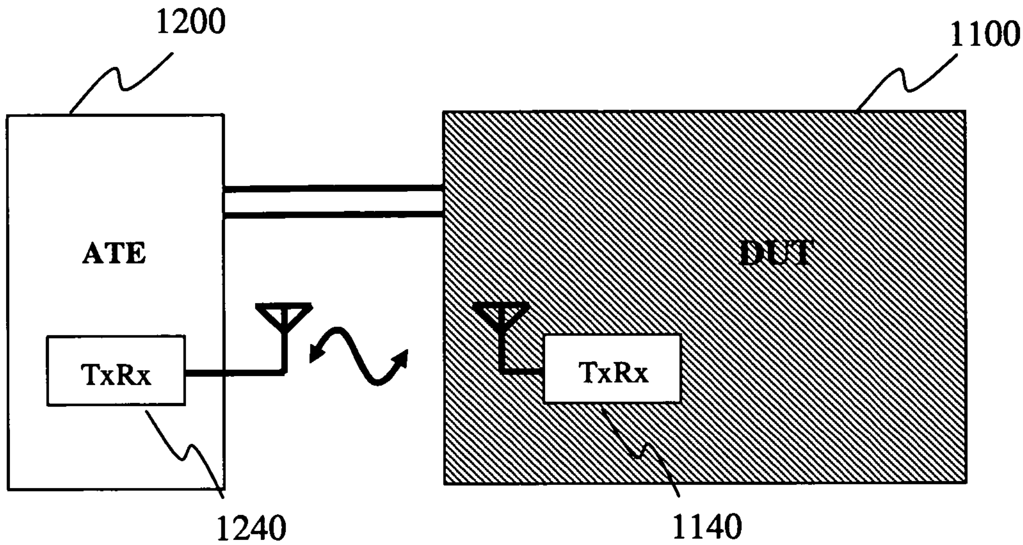
111
112-612, 701-704
810
Antenna
860
Circuit 1
850
112'-612', 701'-704'
111'

Fig. 22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1100
ATE
DUT
TxRx
TxRx
1240
1140

Fig. 23

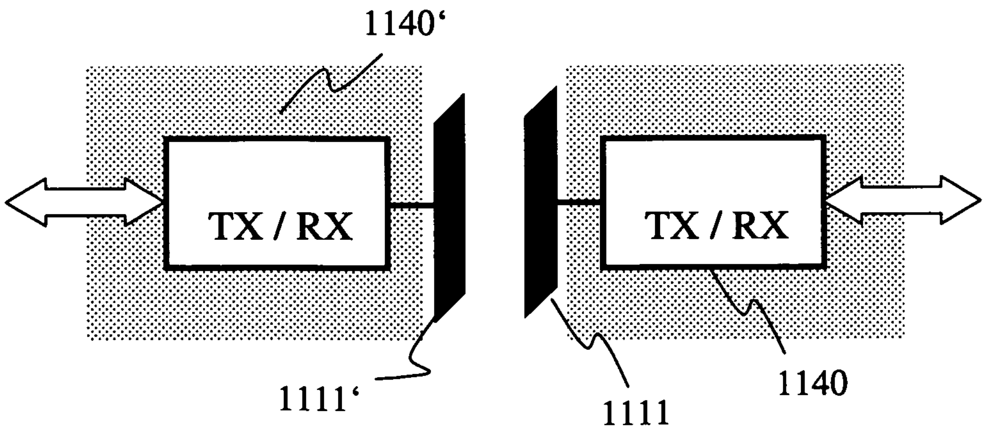
1140‘
TX / RX
TX / RX
1111‘
1111
1140

Fig. 24

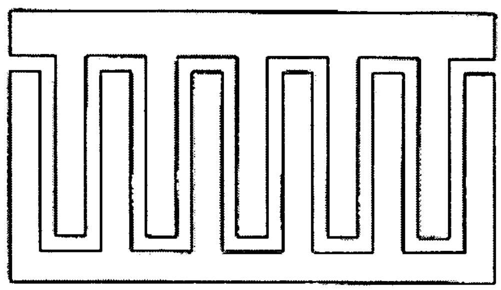

Fig. 25a

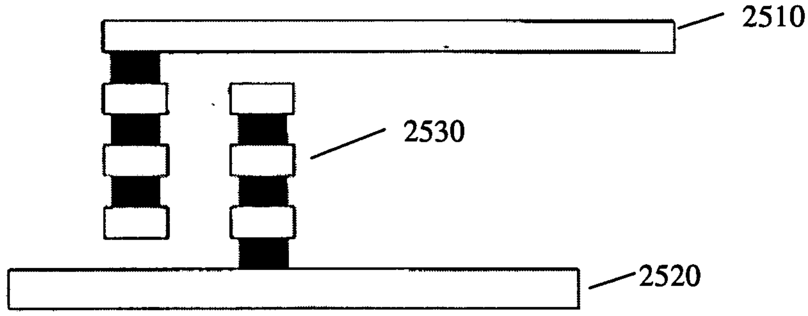

Fig. 25b

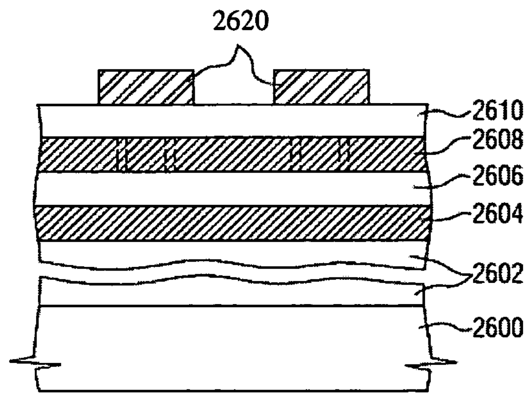

Fig. 26

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2011/006449

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01L23/522
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)
H01L

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 practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2 242 101 A2 (ORACLE AMERICA INC [US]) 20 October 2010 (2010-10-20) paragraph [0054]; claim 1; figure 4 -----	1,2,9,10
X	EP 1 696 487 A1 (ATMEL GERMANY GMBH [DE]) 30 August 2006 (2006-08-30) paragraph [0034]; claim 1; figure 1 -----	1,9,10
Y	JP 2008 205403 A (NEC CORP) 4 September 2008 (2008-09-04) abstract; figures 1A,1B,3B -----	1-10
Y	DE 100 46 910 A1 (MITSUBISHI ELECTRIC CORP [JP]) 10 May 2001 (2001-05-10) column 9, line 63 - column 11, line 19; figures 21,24,25,28 -----	1-10

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"E" earlier document 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
29 March 2012	05/04/2012

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Zeisler, Peter

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2011/006449

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
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			US	6465832	B1	15-10-2002