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(54) Miniature broadband antenna with inductive chassis coupling

Kleine, Breitbandigeantenne mit Induktive Chassiskopplung

Antenne a large bande miniature avec couplage inductif du châssis

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- **PATENT ABSTRACTS OF JAPAN vol. 2003, no. 12, 5 December 2003 (2003-12-05) -& JP 2004 040524 A (MURATA MFG CO LTD), 5 February 2004 (2004-02-05)**

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Description

[0001] The present invention relates to a means for transmitting and receiving electromagnetic waves, and in particular to a built-in antenna for use in portable electronic equipment for wireless communication.

[0002] Portable electronic equipment for wireless communication and in particular those used as mobile radio terminals in wireless communication networks like e.g. mobile telephones, pagers, communicators, electronic organisers, smartphones, PDA's (Personal Digital Assistants), or the like are designed to show a small form factor, i.e. they are designed for providing a multitude of functions and services within a housing of very compact dimensions.

[0003] For achieving portable electronic equipment with very compact dimensions, an antenna required for a communication with a wireless communication network is usually integrated within the housing of a respective electronic appliance. Various types of built-in antenna concepts have been developed that allow design an antenna small enough for fitting in a small form factor casing of a portable electronic equipment for wireless communication. Hereby, technologies are favoured, which enable a design of thin antennae elements, since flat antennae can be integrated more conveniently within a small casing than others. Microstrip antennae formed by a conducting patch on a grounded microwave substrate are the most commonly used antenna type.

[0004] The term antenna as used in this specification covers any means that is adapted to emit or receive electromagnetic waves. A respective radiator converts at least part of an incident free space electromagnetic wave into a conductor bound wave and vice versa. The term antenna is therefore not restricted to any particular known embodiment, but is to be understood in the above generic meaning.

[0005] The lateral dimensions of a conventional microstrip antenna match a half wavelength resonance at the desired frequency. A further reduction of the lateral dimensions of a microstrip antenna below a half wavelength resonance is achieved by a so-called PIFA (Planar Inverted F Antenna) type antenna, the name of which is derived from the antenna's geometry when seen in a cross-sectional view. The bandwidth of a respective antenna is strongly affected by the spacing between the radiating antenna patch and the antenna ground plate, whereby a reduction of the spacing leads to a reduction of the antenna's bandwidth.

[0006] PIFA-type antennae for broadband applications require a thick spacing between the radiating antenna patch and the antenna ground plate and impose therefore a considerable limitation to any attempts for further reducing the size of portable electronic equipment for wireless communication. Moreover, the bandwidth achievable with PIFA-type antennae at low frequency bands is generally not satisfactorily, and for the DVB-H (Digital Video Broadcasting for Handheld Devices) band that is currently on the industries roadmap, and which operates in a band from 470 MHz to 702 MHz, it is generally not acceptable.

[0007] The correlation of a PIFA-type antenna's spacing with the antenna bandwidth is therefore the limiting factor for the usefulness of this antenna type for miniaturised portable electronic equipment designed to meet the broadband requirements of present-day mobile communication systems.

[0008] To achieve a more effective radiation on miniaturised mobile radio equipment, use is made of the so-called chassis of a respective equipment. The chassis is formed by electrically conductive elements of the printed circuit board (PCB) and the EMC (Electromagnetic Compatibility) shielding, which often create a solid metal ground plane. At low frequencies, i.e. when the length of the chassis is less than a wavelength, the chassis operates like a thick dipole antenna because it has the same kind of current distribution. In this case, the maximum current density is located near the centres of the long edges, while the current density takes on small values along the short edges. Due to its similar current distribution, the electric fields of an antenna coupled to the chassis mode are like that of a dipole antenna. The bandwidth of an antenna implemented as a respective chassis mode exciter, usually referred to as chassis mode antenna, is strongly affected by the dimensions of the chassis. For a given structure, the highest bandwidth is achieved when the chassis is operated at half-wave resonance.

[0009] The chassis dimensions of present-day electronic equipment for wireless communication are typically too short for a low-band resonance and too long for a high-band resonance. For optimising the radiation properties, the electrical length of the chassis, that is the resonance length of its conductive structure, has to be adapted to the resonance wavelength. For a bar-type mobile radio terminal a capacitive chassis mode coupler is known to serve this purpose (see for instance: J. Holopainen, "Antenna for Handheld DVB Terminal", Master's thesis, Helsinki University of Technology, Espoo, May 2005, or P. Vainikainen, J. Ollikainen, O. Kivekas, and I. Kelander, "Resonator-based analysis of the combination of mobile handset antenna and chassis", IEEE Trans. Antennas Propagat.,Vol. 50, No. 10, pp. 1433-1444, Oct. 2002).

[0010] Present-day portable electronic equipment for wireless communication systems has to support multistandard and multiband communication. This requires antennae that are matched for different frequency bands, since different wireless services are provided on different transmission channels. Coverage for the GSM (Global System for Mobile Communication) bands operating at 850 MHz and 900 MHz, the DCS (Digital Cellular System) band operating at 1800 MHz, the PCS (Personal Communication Service) band operating at 1900 MHz, the UMTS (Universal Mobile Telecommunication Systems) bands operating at frequencies of up to 2.2 GHz, the ISM (Industrial, Scientific, and Medial) band at 2.4 GHz, and

for the above mentioned DVB-H (Digital Video Broadcasting for Handheld Devices) band has to be provided. Accordingly, the electrical length of an antenna coupled to the chassis mode has to be adapted to the different transmission channels.

[0011] Since the surface area of many miniaturised wireless communication appliances is often too small for accommodating all desired user interface elements like a keypad, display, camera lens or the like, two-part casings providing a twofold surface area at the same volume size are often used. The casing parts are either hinged for a fold-away operation (folder-type like e.g. clam-shell mobile radio phones), for enabling a pivoting or twisting movement or a sliding movement of the two casing parts with respect to each other. Sometimes these opening mechanisms are combined. In the open state, the chassis is composed of two interconnected large-area components, which are located side by side at an obtuse angle.

[0012] A capacitive coupling of a chassis mode antenna requires a huge volume at one end of the chassis and is further sensitive to any dielectric influences from outside the chassis like e.g. a finger of a user. For DVB-H applications, the space required for a respective capacitive coupling element is estimated to be around 3 cm^3, which is far too much for present-day portable electronic equipment for wireless communication.

[0013] EP 1 422 787 A1 relates to an antenna composed of two ground conductors, connection means for connecting these ground conductors together, and a feeder for feeding power to a part of the connection means.

[0014] EP 1 258 943 A1 discloses a foldable portable telephone. A shield box provided with an upper casing is connected via a flexible cable to an output terminal of a transmitting circuit provided within a lower casing, and the shield box is used as an antenna.

[0015] WO 2005/050780 relates to improving the characteristic of an antenna of a mobile telephone to reduce the SAR while preventing the gain of the antenna from decreasing during a call.

[0016] It is an object of the present invention to provide a chassis mode antenna for small volume portable electronic equipment for wireless communication, which elements add practically no additional volume beyond the chassis size.

[0017] This object is achieved by the invention as defined in the independent claims. Further developments are set forth in the dependent claims.

[0018] In particular, the object is achieved by an antenna for use in portable electronic equipment for wireless communication, with the antenna comprising a first chassis element of the portable electronic equipment, a second chassis element of the portable electronic equipment, an interconnection element for galvanically interconnecting the first chassis element with the second chassis element, and an inductive coupling element that is adapted to inductively couple to a current on the first chassis element, the second chassis element, and the interconnection element. A first antenna-feeding terminal is connected to ground of the first chassis element. The geometrical form of the first chassis element, the second chassis element, and the interconnection element is designed for the electrical length of the chassis formed by the first chassis element, the second chassis element, and the interconnection element to correspond to an odd multiple of a half-wavelength resonance at a specified frequency. The inductive coupling element comprises a first conducting line, the first end of which is electrically connected to ground of the first chassis element and the second end of which is electrically connected to an electrode of a tuning capacitor having its other electrode electrically connected to ground of the second chassis element. The capacitance of said tuning capacitor is thereby dimensioned for the input impedance between the first feeding terminal and the second feeding terminal to be of a defined and substantially real value at the specified frequency. According to the invention, for adjusting the input impedance to a desired value, the inductive coupling element comprises a further conducting line extending from the first conducting line at a location between the first end and the second end of said first conducting line to the second antenna feeding terminal, while the first end of the first conducting line is electrically connected to ground of the first chassis element.

[0019] The above object is further achieved by portable electronic equipment for wireless communication having a respective antenna.

[0020] An antenna according to the invention combines a small volume with a large bandwidth, which is due to the utilisation of the whole chassis by the strong inductive coupling between the chassis mode and the inductive coupler. Since the implementation of the antenna requires only an addition of a capacitor and an additional conducting line to the connection between the chassis elements, it is simple to realise and inexpensive.

[0021] It should be noted in this context that the terms "comprise", "comprises", and "comprising" as well as grammatical modifications thereof indicate when used in this specification the presence of technical features like stated components, figures, integers steps or the like, and do by no means preclude a presence or addition of one or more other features, particularly other components, integers, steps or groups thereof. The same applies to the term "includes" and its grammatical modifications when used in this specification.

[0022] For achieving a small volume, low-cost conducting line with excellent high frequency properties, the first conducting line is preferably formed by a strip line.

[0023] The first conducting line may be arranged either laterally or vertically displaced with respect to the interconnection connecting the first chassis element with the second chassis element, thereby extending the scope for a design of the inductive coupling element by enabling a very versatile construction of the loop enclosing the magnetic flux that is adapted to the conditions set by the mechanical implementation of a hinge between the first

and the second chassis element.

[0024] For high frequencies with its shorter wavelength it is advantageous to adjust the electrical length of the antenna to a three half-wavelength resonance. Hereunto, the interconnection element for galvanically interconnecting the first chassis element with the second chassis element is adapted for the total length of the joint together edge elements extending on one side of the interconnection element from the neighbouring corner of a lateral edge of the first chassis element via the interconnection element to the neighbouring corner of a lateral edge of the second chassis element to correspond to an electrical length of a half-wavelength for a specified frequency. A lateral edge of a chassis element is an edge along those sides of the chassis element, which are more or less perpendicular to the chassis side connected to the interconnection element. In a preferred embodiment, the lateral edges of the first chassis element and the second chassis element are each advantageously adapted for accommodating a half-wavelength at the specified frequency, thereby rendering the chassis formed by the first chassis element, the second chassis element, and the interconnecting element resonant to three half-wavelength at the specified frequency.

[0025] For matching the antenna to different frequency bands, as usually required for multi-standard communication, the antenna advantageously comprises a further inductive coupling element that is adapted to inductively couple to a further current on the first chassis element, the second chassis element, and the interconnecting element, corresponding to a different odd multiple of a half-wavelength resonance at a further specified frequency

[0026] On present-day portable electronic equipment for wireless communication, the position of the second chassis element relative to the first often depends on the wireless service just used. When used for phone applications, the chassis elements will most probably enclose an obtuse angle while when in stand-by mode or when used for watching video television, the chassis elements are more likely in a different position, like e.g. in a more or less stacked arrangement. With the antenna optimised for just one position like e.g. the open position where both chassis elements form a more or less obtuse angle, a mismatch of the antenna in the other position is very likely. According to an advantageous development, the antenna further comprises a capacitive coupling element and a switching element, which is adapted to switch between the inductive coupling element and the capacitive coupling element as a function of the angle between the first chassis element of the portable electronic equipment for wireless communication and the second chassis element of the portable electronic equipment for wireless communication. In an alternative embodiment, the antenna comprises a PIFA-type antenna and a switching element, which is adapted to switch between the inductive coupling element and the capacitive coupling element as a function of the angle between the first chassis element of the portable electronic equipment for wireless communication and the second chassis element of the portable electronic equipment for wireless communication.

[0027] Since a matching of an inductively coupled antenna with two interconnected chassis elements is relatively uncritical up to a certain defined angle between the two chassis elements, the switching element is preferably adapted to switch between the inductive coupling element and the capacitive coupling element or the PIFA-type antenna element within a small angular interval at a defined angle between the first chassis element and the second chassis element.

[0028] To avoid problems induced by corrosion or staining of contact surfaces, the switching element is favourably formed by a capacitive switch. In a preferred embodiment, the capacitive switch comprises two variable capacitors, each of which is adapted to vary its capacitance in dependence of the angle between the first chassis element and the second chassis element and opposite to the respective other variable capacitor.

[0029] In the following, the present invention is explained in more detail with respect to special embodiments and with reference to the enclosed drawings, in which

Figure 1 shows a schematic of the basic concept of an antenna with an inductive coupler,

Figure 2 shows an example being not part of claimed invention of an antenna with an inductive coupler together with an indication of the magnetic field and the current distribution at the inductive coupling element,

Figure 3 shows an embodiment according to invention of an antenna with an inductive coupler and an indication of the magnetic field and the current distribution at the inductive coupling element,

Figure 4 shows an example being not part of claimed invention of an antenna according to Figure 1,

Figure 5 schematically shows an example being not part of claimed invention of chassis formed of a first conducting chassis element, a second conducting chassis element and a conducting connection element together with an indication of the distribution of the current density on the plain chassis when electromagnetically excited along its longitudinal axis,

Figure 6 shows an example being not part of claimed invention of an inductively coupled antenna adapted for multi band applications in a schematic representation,

Figure 7 shows an example being not part of claimed invention of an antenna using an inductive coupling element for only one operating condition,

Figure 8 shows two operating conditions of a two-capacitor switching element,

Figure 9 shows a simulated antenna characteristic for an antenna according to a first example tuned for DVB applications,

Figure 10 shows a simulated antenna characteristic for an antenna according to a first embodiment tuned for GSM applications,

Figure 11 shows a simulated antenna characteristic for an antenna according to an example tuned for DCS, PCS, and UMTS-1 (frequency band for UMTS in ITU region 1) applications,

Figure 12 shows a simulated antenna characteristic for an antenna according to an example tuned for dual feed GSM 850, GSM 900, GSM 1800, GSM 1900, UMTS-1, and ISM 2.4 GHz band applications.

[0030] The basic concept of an antenna for use in portable electronic equipment for wireless communication implemented with an inductive coupling element is shown in form of a schematic representation in Figure 1. Only those components necessary for the understanding of the present invention are indicated in the figure. Further components, which may be necessary for an operation of a respective antenna like e.g. a feeding circuit, matching circuit or the like have been omitted for the sake of clarity but are deemed as components present in the equipment if required. Objects and their details are not shown to scale in the figures.

[0031] The term portable electronic equipment for wireless communication includes mobile radio communication equipment, which is also referred to as a mobile radio terminal, a collective term comprising all equipment such as mobile telephones, pagers, and communicators like electronic organisers, smartphones or the like more.

[0032] The antenna 100 according to Figure 1 shows three main components, a first chassis element 1, a second chassis element 2 connected to the first chassis element by a connection element 3, and an inductive coupling element. The inductive coupling element is formed by the interconnection element 3 located between the first chassis element 1 and the second chassis element 2, a conducting line 5 extending from the first chassis element 1 to an electrode of a capacitor 6, which other electrode is terminated against ground of the second chassis element 2.

[0033] Having two chassis elements connected by an interconnection element 3 as shown in Figure 1 is very common for portable electronic equipment like folder-type or sliding-type mobile radio terminals. The interconnection 3 is usually formed by a flexible PCB (Printed Circuit Board) having a contiguous conducting shield, which connects the two chassis elements and encloses the tracks for electrical connections between the two chassis elements formed on the PCB. The conducting shield provides the connection element with a defined length and geometry and defines the connection points to the chassis elements. One chassis element is accommodated within the base part of a folder-type mobile radio terminal, the other in the flip or slidable part. Since an electronic equipment's transceiver is most commonly housed in the base part of a respective appliance, the first chassis element will in this description also be addressed as base part chassis while the other chassis element will be addressed as flip part chassis. These denominations are arbitrary and mean no restriction to the invention. They only serve a more comprehensive explanation of the present invention. Since a transceiver may as well be housed in the flip part and since the feeding terminals of an antenna may be located in a different part of the equipment than the transceiver, a person skilled in the art will well understand that the first chassis element 1 might as well form the flip part chassis while the second chassis element 2 might form the base part chassis.

[0034] Figure 2 shows a more detailed view of the section indicated by the dashed line in Figure 1. The antenna 100 requires basically a conducting line 5, which is terminated at one of its ends against ground with a tuning capacitor 6. As ground, a PCB ground or conductive housing of the flip part chassis 2 may be used. The capacitor 6 itself may be formed as a lumped element or formed by a patch on the PCB of the chassis element. The other end 7a of the conducting line 5 is e.g. located at the base part chassis and serves as a feeding terminal for the antenna 100. A receiver or transmitter is connected between the terminals 7a and 7b, the latter being connected to PCB ground or conductive housing of the base part chassis 1.

[0035] An incoming electromagnetic wave induces a current density on the chassis of a mobile radio terminal that can be decomposed into characteristic chassis modes. Chassis modes which resonance frequency is close to the operating frequency of the mobile radio terminal are hereby dominantly excited. The term operating frequency refers to a frequency specified for a certain or current operation of the portable equipment for wireless communication. When a dipole-type current distribution is excited, the total electrical length of the chassis, i.e. the two chassis elements 1 and 2 including the interconnection element, corresponds to about a half-wavelength at the operating frequency. The maximum induced current density appears near the centre of the open structure of the antenna 100, basically on the interconnection element 3 between the base part and the flip part of the

mobile radio appliance, i.e. typically on the shield of a flexible PCB interconnection 3 as indicated by the arrows in Figure 2. The induced current on the interconnection gives rise to a surrounding magnetic field 4 that is indicated in Figure 2 by circular enclosed crosses.

[0036] Due to the induced magnetic flux 4 enclosed by the loop consisting of the interconnection element 3, the capacitor 6, and the conducting line 5, a voltage is induced between the terminals 7a and 7b. A suitably selected capacitance 6 enables to tune the input impedance of the inductive coupler at the terminals 7a and 7b for the operating frequency to take on a substantially real value of the desired magnitude. In other words, the capacitance of the capacitor 6 is the key to tune the loop and with that the antenna structure 100 to resonate at the operating frequency. Due to its inductive functionality, the principle of the described arrangement is in this specification referred to as an inductive coupler or inductive coupling element.

[0037] The conducting line 5 can take on any form like e.g. that of a single wire. For adjusting its high frequency characteristics, however, a microwave compatible design is preferred, and effectively implemented by a strip line.

[0038] An embodiment according to the current invention of an inductive coupler is shown for an antenna 200 in Figure 3. The conducting line 5 is again capacitively terminated at the flip part while the base part end is directly connected to PCB ground or a conductive housing of the base part. The conducting line 5 is tapped at an appropriate position with another conducting line 8 for implementing a feeding terminal 9a, 9b of desired input impedance. The tapped line, which is preferably formed by a strip line for the first conductive line 5 being formed by a strip line works as an impedance transformer.

[0039] The interconnection element 3 and the conducting line 5 as shown in Figures 1, 2, and 3 both resemble a common shape for interconnections used to facilitate bending, but it is to be noted that the S-like shape of the interconnection element 3 is not essential for the working of the inductive coupling element. Any other shape like e.g. a straight interconnection or strip may be used instead.

[0040] Further also the lateral displacement of the conducting line 5 with respect to the interconnection element 3 as shown in Figures 2 and 3 is not essential. A vertical displacement like a stacked arrangement of conducting line 5 and interconnection element 3 may also be used instead. The conducting line 5 may be placed on top of the interconnection element 3 as shown for the antenna 300 in Figure 4 but also below it. A distance of 1 to 2 mm between the interconnection element 3 and the coupling conducting line is sufficient. In obvious analogy to Figure 3, the embodiment using the tapped conducting line 8 to the feeding terminal may as well be implemented in a stacked arrangement.

[0041] The described embodiments favour a dominant excitation of a half-wavelength chassis mode where the electrical length of the total chassis formed by the first chassis element, the connection element and the second chassis element equals approximately a half wavelength of the operating frequency of a portable electronic equipment employing an antenna structure 100, 200 or 300. A respective dominant excitation is observed for the typical dimensions of an open state folder-type mobile radio terminal in the range from 500 MHz to 1 GHz. This includes the GSM850, GSM900, and DVB bands.

[0042] A simulated characteristic of an inductively coupled antenna for the DVB applications is shown in Figure 9. The antenna structure used for the simulation is indicated above the diagram. It corresponds to an antenna structure described with respect to Figures 1 and 2. The diagram shows the magnitude of the input reflection coefficient at the antenna feed point referenced to 50 Ohm in decibels versus the operating frequency. A return loss of at least 8 dB is achieved in the frequency range from 500 MHz to 850 MHz. The limits of the frequency range are indicated by open arrow 1 and open arrow 2, respectively.

[0043] Figure 10 shows a simulated characteristic of an inductively coupled antenna for GSM850/GSM900 applications. A good impedance match is observed for the antenna structure shown above the diagram in the frequency range from 824 MHz to 960 MHz as indicated by the open arrows referenced 1 and 2. The antenna structure used for the simulation is also a representative of the principle structure described with respect to Figures 1 and 2.

[0044] The described examples are in principle also applicable for higher frequency applications like DCS, PCS, and UMTS if tuned by a proper selection of the capacitance 6. Nevertheless it is very likely, that the physical dimensions of a folder-type phone chassis are much bigger than a half-wavelength at these frequencies, so that the chassis is preferably operated at a three half-wavelength resonance for these frequencies.

[0045] Hereto a different chassis mode is utilised. The schematic of Figure 5 indicates the current density orientation along the edges of the PCB ground of the base part chassis 1 and the flip part chassis 2 of a folder type radio appliance for a three half-wavelength resonance. Current density nodes occur near the hinge side vertices of the base part PCB ground and the flip part PCB ground. Currents on the base part 1 and the flip part 2 are exited in phase by an incident wave, which is polarised along the long axis of the open folder-type radio terminal. Each chassis element 1 or 2 thus absorbs a half-wavelength. Another half-wavelength can be absorbed in the slot 10 formed on one side of the interconnection element 3 by all contiguous edges between two facing corners on a lateral side of the two chassis elements. The half-wavelength slot 10 is indicated in Figure 5 by a double-arrowed line marked with "~λ/2". Its circumferential length is designed to render approximately a half-wavelength at a specified operating frequency. The direction of the current at the interconnection element 3 is opposite to the

direction of the current along the base and the flip parts for the assumed conditions. Since it is mostly orthogonal in direction and compensated by currents along adjacent edges of the base and flip PCB ground, the coupling of the currents to the incoming electromagnetic wave is weak. The overall current distribution therefore couples mostly constructively with an incoming wave, but has an increased electrical length of roughly two half-wavelength.

[0046] The described example 400 enables an antenna with a very large bandwidth as is shown in the simulation example given in Figure 11. The antenna structure used for the simulation corresponds to the type shown in Figure 5, and is shown on top of the diagram with the antenna characteristic. The frequency region, which is usable for DCS, PCS, and UMTS-1 applications is marked by the open arrows labelled with number 1 and number 2. It stretches from 1.7 GHz to 2.17 GHz.

[0047] If the slots 10 and 11 indicated in Figure 5 are designed in accordance to the rules stated above for slot 10, they may also be looked at as quarter-wave slot-line impedance transformers between the current on the interconnection element (and inductive coupler) and the current along the edges of the base and flip part PCB ground.

[0048] Figure 6 shows a dual-frequency antenna system with two separate paired antenna feeding points for separate frequency bands. The shown structure is based on the antenna concept of Figure 1. The dual antenna system 500 is implemented by placing a second inductive coupler comprising antenna feeding terminal 11a and capacitor 12 near the interconnection element 3. Either the lateral or the stacked, i.e. vertical arrangement of conducting line 5 and interconnection element 3, or a combination of both can be used to implement the two inductive couplers. In Figure 6, the lateral arrangement is shown. Like for a single-band antenna described above, either a directly fed inductive coupler or a tapped line inductive coupler, i.e. a coupler with a built-in impedance transformer can be used. A simulation result of a dual-frequency, dual-feed antenna according to the concept of Figure 6 is given in Figure 12 for dual feed GSM 850, GSM 900, GSM 1800, GSM 1900, UMTS-1, and ISM 2.4 GHz band applications. The antenna structure used for the simulation is shown on top of the diagram with the characteristics. The antenna is matched to a first frequency band between 820 and 960 MHz (indicated by open arrows number 1 and 2) and a second frequency band stretching from 1.7 GHz to about 2.17 GHz (indicated by open arrows 3 and 4).

[0049] Also the inductive coupler concept has been described with respect to a two-part chassis, it is also applicable to a bar type chassis where the two chassis elements are to be regarded as being merged with the connection element. The inductive coupling element, i.e. the conducting line 5 with the capacitor 6 is in this case just placed over the middle line of the bar-type chassis.

[0050] In a further example an antenna structure according to one of the above described is combined with a different kind of antenna optimised for a closed state of a folder-type portable electronic equipment for wireless communication. A switching element activates the antenna type that is best suited for a selected operating condition of the folder-type electronic appliance.

[0051] The switching element is preferably implemented as a capacitive switch enabling contactless switching and thus avoiding problems due to corrosion or staining of contact surfaces. The principle of a respective antenna combination is shown in the representation of Figure 7. The upper representation of Figure 7 shows an inductive coupler antenna according to an embodiment of the present invention used for the open state of a folder-type mobile radio terminal. This antenna provides the terminal 13 as an antenna feeding point. The lower left representation shows the flip part 2 in a position forming a 90 degree angle with the base part 1, whereby it is assumed, that this angle forms the critical transition angle between the open position and the closed position of the appliance. In this position, a different antenna is used, which provides a terminal 14 as a feeding point. This antenna can be implemented as a capacitive coupled chassis mode antenna but also as a conventional PIFA-type antenna or a different type of microstrip antenna. In the lower right representation, an example for a capacitive switch is given, using two capacitors 16 and 17, which capacitances vary with the angle between the base part 1 and the flip part 2 in opposite directions.

[0052] In the open state of the folder-type appliance, the capacitance 16 is very large while the capacitance 17 is very small. The output 15 of a transceiver is in this case connected to the inductive coupler's feeding point 13. In the closed state, the capacitance 16 is very small while the capacitance 17 is very large, so that the output 15 is connected to the second antenna's feeding point 14, e.g. to the feeding point of a capacitive coupler. Changing the angle between the first chassis element 1 and the second chassis element 2 varies the capacitances of the variable capacitors 16 and 17. This is usually done when opening or closing the folder-type appliance. The transition between the two switching states, i.e. between a connection of terminal 15 to terminal 13 and a connection of terminal 15 to terminal 14, is preferably restricted to a small angular interval at a defined angle. Since the inductive coupled antenna operates well down to an angle of about 90 degree, the transition angle is preferably set near an angle of 90 degrees. For smaller angles the capacitive coupler or an alternative antenna is used, for larger angles the inductive coupler antenna is used.

[0053] A switch with a respective behaviour may be implemented in many ways like for instance by pivotable electrodes arranged around the axis of rotation of a folder-type casing, which form together with adjacent not pivotable electrodes rotation angle dependent capacitances.

[0054] A further example of a capacitive switch accord-

ing to the principle shown in Figure 7 is shown in Figure 8. A plate 18 is flapped between two positions to be near a first electrode in the closed position and near a second electrode in the open position of the folder type casing. The plate may be formed by a prestressed spring electrode 18 being switched between its two stable positions shown in the top and the bottom representation respectively by means of a lever like mechanism 19.

[0055] A switch according to the above described may also be activated by a relative motion of the chassis elements on opening or closing the electronic equipment. For folder-type electronic equipment, the pivoting motion of the chassis elements may be used, for other types a sliding motion or a twisting motion may be preferred.

[0056] An inductive coupling element as described in this specification has extremely small volume requirements as it adds only a conducting line and a capacitor to the already existing chassis. It therefore enables the realisation of small and low cost chassis mode antennae for folder-type portable electronic equipment for wireless communication. Due to the minimal component addition, it has also to be considered as a very low cost solution. Furthermore, the inductive coupling is insensitive to outside interference, particularly to dielectric changes in the vicinity, and provides also a higher bandwidth than common antenna concepts.

Claims

1. Antenna for use in portable electronic equipment for wireless communication, the antenna (100, 200, 300, 400, 500) comprising

- a first chassis element (1) of the portable electronic equipment for wireless communication having a first antenna feeding terminal (9b) connected to ground of the first chassis element (1),
- a second chassis element (2) of the portable electronic equipment for wireless communication,
- an interconnection element (3) for galvanically interconnecting the first chassis element (1) with the second chassis element (2), and
- an inductive coupling element (5) for inductively coupling to a current on the first chassis element (1), the second chassis element (2), and the interconnection element (3), the inductive coupling element comprising a first conducting line (5) and a tuning capacitor (6), whereby the first conducting line (5) comprises a first end being electrically connected to ground of the first chassis element (1) and a second end being electrically connected to an electrode of said tuning capacitor (6), which other electrode is electrically connected to ground of the second chassis element (2),

wherein

- the geometrical form of the first chassis element (1), the second chassis element (2), and the interconnection element (3) is designed for the electrical length of the chassis formed by the first chassis element (1), the second chassis element (2), and the interconnection element (3) to correspond to an odd multiple of a half-wavelength resonance at a specified frequency, and
- the capacitance of the tuning capacitor (6) is dimensioned for the input impedance between the first feeding terminal (9b) and the second feeding terminal (9a) to be of a defined and substantially real value at the specified frequency,

characterised by
the inductive coupling element comprising a further conducting line (8) extending from the first conducting line (5) at a location between the first end and the second end of said first conducting line (5) to the second antenna feeding terminal (9a), while the first end of the first conducting line is electrically connected to ground of the first chassis element (1).

2. Antenna according to claim 1,
characterised in
that the first conducting line (5) is formed by a strip line.

3. Antenna according to claim 1 or 2,
characterised in
that the first conducting line (5) is arranged laterally displaced to the interconnection element (3) connecting the first chassis element (1) with the second chassis element (2).

4. Antenna according to claim 1 or 2,
characterised in
that the first conducting line (5) is arranged vertically displaced to the interconnection element (3) connecting the first chassis element (1) with the second chassis element (2).

5. Antenna according to one of the claims 1 to 4,
characterised in
that the interconnection element (3) for galvanically interconnecting the first chassis element (1) with the second chassis element (2) is adapted for the total length of the joint together edge elements extending on one side of the interconnection element (3) from the neighbouring corner of a lateral edge of the first chassis element (1) via the interconnection element (3) to the neighbouring corner of a lateral edge of the second chassis element (2) to correspond to an electrical length of a half-wavelength for a specified frequency.

6. Antenna according to claim 5,
characterised by
the lateral edges of the first chassis element (1) and the second chassis element (2) each being adapted for accommodating a half-wavelength at the specified frequency, thereby rendering the chassis formed by the first chassis element (1), the second chassis element (2), and the interconnecting element (3) resonant to three half-wavelength at the specified frequency.

7. Antenna according to one of the claims 1 to 6,
characterised by
the antenna (100, 200, 300, 400, 500) comprising a further inductive coupling element that is adapted to inductively couple to a further current on the first chassis element (1), the second chassis element (2), and the interconnecting element (3), corresponding to a different odd multiple of a half-wavelength resonance at a further specified frequency,
wherein preferably the inductive coupling element is connected at one end to a second antenna feeding terminal located on the first chassis element and connected at a second end to a terminal of a second capacitor, said second capacitor has its other terminal connected to the second chassis element,
the interconnection element is preferably located between both inductive elements.

8. Antenna according to one of the claims 1 to 7, **characterised by**

- a capacitive coupling element and
- a switching element (16, 17), which is adapted to toggle between the inductive coupling element and the capacitive coupling element as a function of the angle between the first chassis element (1) of the portable electronic equipment for wireless communication and the second chassis element (2) of the portable electronic equipment for wireless communication.

9. Antenna according to one of the claims 1 to 7, **characterised by**

- a PIFA-type antenna element and
- a switching element (16, 17), which is adapted to toggle between the inductive coupling element and the capacitive coupling element as a function of the angle between the first chassis element (1) of the portable electronic equipment for wireless communication and the second chassis element (2) of the portable electronic equipment for wireless communication.

10. Antenna according to claim 8 or 9,
characterised in
that the switching element is adapted to toggle between the inductive coupling element and the capacitive coupling element or the PIFA-type antenna element within a small angular interval at a defined angle between the first chassis element (1) and the second chassis element (2).

11. Antenna according to one of the claims 8 to 10,
characterised in
that the switching element (16, 17) is formed by a capacitive switch.

12. Antenna according to claim 11,
characterised in
that the capacitive switch comprises two variable capacitors (16, 17), with each variable capacitor being adapted to vary the capacitance depending on the angle between the first chassis element and the second chassis element and opposite to the respective other variable capacitor.

13. Portable electronic equipment for wireless communication comprising an antenna according to one of the claims 1 to 12.

Patentansprüche

1. Antenne zur Verwendung in einem tragbaren elektronischen Gerät zur drahtlosen Kommunikation, wobei die Antenne (100, 200, 300, 400, 500) umfasst:

- ein erstes Chassiselement (1) des tragbaren elektronischen Geräts zur drahtlosen Kommunikation, das einen ersten Antennenspeisungsanschluss (9b) aufweist, der mit einer Erdung des ersten Chassiselements (1) verbunden ist,
- ein zweites Chassiselement (2) des tragbaren elektronischen Geräts zur drahtlosen Kommunikation,
- ein Verbindungselement (3) zum galvanischen Verbinden des ersten Chassiselements (1) mit dem zweiten Chassiselement (2), und
- ein induktives Kopplungselement (5) zum induktiven Koppeln an einen Strom auf dem ersten Chassiselement (1), dem zweiten Chassiselement (2) und dem Verbindungselement (3), wobei das induktive Kopplungselement eine erste leitfähige Leitung (5) und einen Einstellkondensator (6) umfasst, wobei die erste leitfähige Leitung (5) ein erstes Ende umfasst, das elektrisch mit der Erdung des ersten Chassiselements (1) verbunden ist, und ein zweites Ende, das elektrisch mit einer Elektrode des Einstellkondensators (6) verbunden ist, wobei die andere Elektrode elektrisch mit einer Erdung des zweiten Chassiselements (2) verbunden ist,

wobei

- die geometrische Form des ersten Chassiselements (1), des zweiten Chassiselements (2) und des Verbindungselements (3) für die elektrische Länge des Chassis entworfen ist, das von dem ersten Chassiselement (1), dem zweiten Chassiselement (2) und dem Verbindungselement (3) gebildet ist, um einem ungeraden Vielfachen einer Halbwellenlängenresonanz bei einer vorgegebenen Frequenz zu entsprechen, und
- die Kapazität des Einstellkondensators (6) für die Eingangsimpedanz zwischen dem ersten Speisungsanschluss (9b) und dem zweiten Speisungsanschluss (9a) dimensioniert ist, um ein definierter und im Wesentlicher realer Wert bei der vorgegeben Frequenz zu sein,

dadurch gekennzeichnet, dass
das induktive Kopplungselement eine weitere leitfähige Leitung (8) umfasst, die sich von der ersten leitfähigen Leitung (5) an einer Stelle zwischen dem ersten Ende und dem zweiten Ende der ersten leitfähigen Leitung (5) zum zweiten Antennenspeisungsanschluss (9a) erstreckt, während das erste Ende der ersten leitfähigen Leitung elektrisch mit der Erdung des ersten Chassiselements (1) verbunden ist.

2. Antenne gemäß Anspruch 1,
dadurch gekennzeichnet, dass die erste leitfähige Leitung (5) von einer Streifenleitung gebildet ist.

3. Antenne gemäß Anspruch 1 oder 2,
dadurch gekennzeichnet, dass die erste leitfähige Leitung (5) seitlich versetzt zum Verbindungselement (3) angeordnet ist, das das erste Chassiselement (1) mit dem zweiten Chassiselement (2) verbindet.

4. Antenne gemäß Anspruch 1 oder 2,
dadurch gekennzeichnet, dass die erste leitfähige Leitung (5) vertikal versetzt zum Verbindungselement (3) angeordnet ist, das das erste Chassiselement (1) mit dem zweiten Chassiselement (2) verbindet.

5. Antenne gemäß einem der Ansprüche 1 bis 4,
dadurch gekennzeichnet, dass das Verbindungselement (3) zum galvanischen Verbinden des ersten Chassiselements (1) mit dem zweiten Chassiselement (2) für die Gesamtlänge der zusammengefügten Elemente ausgelegt ist, die sich auf einer Seite des Verbindungselements (3) von der benachbarten Ecke eines Seitenrandes des ersten Chassiselements (1) über das Verbindungselement (3) zur benachbarten Ecke eines Seitenrandes des zweiten Chassiselements (2) erstrecken, um einer elektrischen Länge einer Halbwellenlänge für eine gegebene Frequenz zu entsprechen.

6. Antenne gemäß Anspruch 5,
dadurch gekennzeichnet, dass
die Seitenränder des ersten Chassiselements (1) und des zweiten Chassiselements (2) jeweils zum Aufnehmen einer Halbwellenlänge bei der gegebenen Frequenz ausgelegt sind, wodurch das Chassis gemacht wird, das durch das erste Chassiselement (1), das zweite Chassiselement (2) und das Verbindungselement (3) gebildet wird, das resonant zu drei Halbwellenlängen bei der gegebenen Frequenz sind.

7. Antenne gemäß einem der Ansprüche 1 bis 6,
dadurch gekennzeichnet, dass
die Antenne (100, 200, 300, 400, 500) ein weiteres induktives Kopplungselement umfasst, das ausgelegt ist, an einen weiteren Strom auf dem ersten Chassiselement (1), dem zweiten Chassiselement (2) und dem Verbindungselement (3) zu koppeln, entsprechend einem unterschiedlichen ungeraden Vielfachen einer Halbwellenlängenresonanz bei einer weiteren gegebenen Frequenz,
wobei vorzugsweise das induktive Kopplungselement an einem Ende mit einem zweiten Antennenspeisungsanschluss verbunden ist, der auf dem ersten Chassiselement liegt, und an einem zweiten Ende mit einem Anschluss eines zweiten Kondensators verbunden ist, der andere Anschluss des zweiten Kondensators mit dem zweiten Chassiselement verbunden ist, das Verbindungselement vorzugsweise zwischen beiden induktiven Elementen liegt.

8. Antenne gemäß einem der Ansprüche 1 bis 7,
gekennzeichnet durch

- ein kapazitives Kopplungselement und
- ein Schaltelement (16, 17), das ausgelegt ist, zwischen dem induktiven Kopplungselement und dem kapazitiven Kopplungselement als eine Funktion des Winkels zwischen dem ersten Chassiselement (1) des tragbaren elektronischen Geräts zur drahtlosen Kommunikation und dem zweiten Chassiselement (2) des tragbaren elektronischen Geräts zur drahtlosen Kommunikation umzuschalten.

9. Antenne gemäß einem der Ansprüche 1 bis 7,
gekennzeichnet durch

- ein Antennenelement vom PIFA-Typ und
- ein Schaltelement (16, 17), das ausgelegt ist zum Schalten zwischen dem induktiven Kopplungselement und dem kapazitiven Kopplungselement als eine Funktion des Winkels zwischen dem ersten Chassiselement (1) des tragbaren

elektronischen Geräts zur drahtlosen Kommunikation und dem zweiten Chassiselement (2) des tragbaren elektronischen Geräts zur drahtlosen Kommunikation.

10. Antenne gemäß einem der Ansprüche 8 oder 9, **dadurch gekennzeichnet, dass** das Schaltelement ausgelegt ist, zwischen dem induktiven Kopplungselement und dem kapazitiven Kopplungselement oder dem Antennenelement vom PIFA-Typ innerhalb eines kleinen Winkelintervalls bei einem gegebenen Winkel zwischen dem ersten Chassiselement (1) und dem zweiten Chassiselement (2) zu schalten.

11. Antenne gemäß einem der Ansprüche 8 bis 10, **dadurch gekennzeichnet, dass** das Schaltelement (16, 17) von einem kapazitiven Schalter gebildet wird.

12. Antenne gemäß Anspruch 11, **dadurch gekennzeichnet, dass** der kapazitive Schalter zwei variable Kondensatoren (16, 17) umfasst, wobei jeder variable Kondensator ausgelegt ist, um die Kapazität in Abhängigkeit des Winkels zwischen dem ersten Chassiselement und dem zweiten Chassiselement und gegenüber dem jeweils anderen variablen Kondensator zu variieren.

13. Portables elektronisches Gerät zur drahtlosen Kommunikation, das eine Antenne gemäß einem der Ansprüche 1 bis 12 umfasst.

Revendications

1. Antenne pour l'usage dans un dispositif électronique portable pour la communication sans fil, l'antenne (100, 200, 300, 400, 500) comprenant:

- un premier élément de châssis (1) du dispositif électronique portable pour la communication sans fil comportant un raccordement d'alimentation d'antenne (9b) connecté à une mise à la terre du premier élément de châssis (1),
- un deuxième élément de châssis (2) du dispositif électronique portable pour la communication sans fil,
- un élément d'interconnexion (3) pour interconnecter galvaniquement le premier élément de châssis (1) au deuxième élément de châssis (2), et
- un élément de couplage inductif (5) pour coupler inductivement à un courant sur le premier élément de châssis (1), le deuxième élément de châssis (2) et l'élément d'interconnexion (3), l'élément de couplage inductif comprenant une première ligne conductrice (5) et un condensateur de réglage (6), la première ligne conductrice (5) comprenant une première fin connectée électriquement à la mise à la terre du premier élément de châssis (1), et une deuxième fin connectée électriquement à une électrode du condensateur de réglage (6), l'autre électrode étant connectée électriquement à la mise à la terre du deuxième élément de châssis (2),
- la forme géométrique du premier élément de châssis (1), du deuxième élément de châssis (2) et de l'élément d'interconnexion (3) étant conçue à la longueur électrique du châssis formé par le premier élément de châssis (1), le deuxième élément de châssis (2) et l'élément d'interconnexion (3) pour correspondre à un multiple impair d'une résonance de demie onde lors d'une fréquence donnée, et

la capacité du condensateur de réglage (6) pour l'impédance d'entrée entre le premier raccordement d'alimentation d'antenne (9b) et le deuxième raccordement d'alimentation d'antenne (9a) étant dimensionnée à être une valeur définie et réelle lors de la fréquence donnée,
caractérisée en ce que
l'élément de couplage inductif comprenant une ligne conductrice (8) s'étendant de la première ligne conductrice (5) par un lieu entre la première fin et la deuxième fin de la première ligne conductrice (5) à la deuxième ligne d'alimentation d'antenne (9a), alors que la première fin de la première ligne conductrice est connectée électriquement à la mise à la terre du premier élément de châssis (1).

2. Antenne selon la revendication 1, **caractérisée en ce que** la première ligne conductrice (5) est formée par une ligne de bande.

3. Antenne selon la revendication 1 ou 2, **caractérisée en ce que** la première ligne conductrice (5) est agencée latéralement décalée à l'élément d'interconnexion (4) qui connecte le premier élément de châssis (1) au deuxième élément de châssis (2).

4. Antenne selon la revendication 1 ou 2, **caractérisée en ce que** la première ligne conductrice (5) est agencée verticalement décalée à l'élément d'interconnexion (3) qui connecte le premier élément de châssis (1) au deuxième élément de châssis (2).

5. Antenne selon l'une des revendications 1 à 4, **caractérisée en ce que** l'élément d'interconnexion (3) pour connecter galvaniquement le premier élément de châssis au deuxième élément de châssis (2) est adapté à la longueur totale des éléments ajointés qui s'étendent sur un côté de l'élément d'in-

terconnexion (3) du coin voisin d'un bord latéral du premier élément de châssis (1) via l'élément d'interconnexion (3) au coin voisin d'un bord latéral du deuxième élément de châssis (2) pour correspondre à une longueur électrique d'une demie longueur d'onde pour une fréquence donnée.

6. Antenne selon la revendication 5,
caractérisée en ce que les bords latéraux du premier élément de châssis (1) et du deuxième élément de châssis (2) sont agencés à recevoir une demie longueur d'onde lors de la fréquence donnée, par lequel le châssis est fait qui est formé par le premier élément de châssis (1), le deuxième élément de châssis (2) et l'élément d'interconnexion (3) résonant à trois demies longueurs d'ondes lors de la fréquence donnée.

7. Antenne selon l'une des revendications 1 à 6,
caractérisée en ce que
l'antenne (100, 200, 300, 400, 500) comprend un élément de couplage additionnel inductif qui est adapté à coupler inductivement à un courant sur le premier élément de châssis (1), le deuxième élément de châssis (2) et l'élément d'interconnexion (3), selon un multiple impair différent d'une résonance de demie longueur d'onde lors d'une fréquence donnée additionnelle,
l'élément de couplage inductif étant connecté de préférence par une fin à un deuxième raccordement d'alimentation d'antenne situé sur le premier élément de châssis et connecté par une deuxième fin à un raccordement d'un deuxième condensateur, le deuxième condensateur comportant son autre raccordement au deuxième élément de châssis, l'élément d'interconnexion étant situé de préférence entre les deux éléments inductifs.

8. Antenne selon l'une des revendications 1 à 7,
caractérisée par

- un élément capacitif de couplage et
- un élément de commutation (16, 17) adapté à commuter entre l'élément de couplage inductif et l'élément de couplage capacitif comme une fonction de l'angle entre le premier élément de châssis (1) du dispositif électronique portable pour la communication sans fil et le deuxième élément de châssis (2) du dispositif électronique portable pour la communication sans fil.

9. Antenne selon l'une des revendications 1 à 7,
caractérisée par

- un élément d'antenne du type PIFA et
- un élément de commutation (16, 17) adapté à commuter entre l'élément de couplage inductif et l'élément de couplage capacitif comme une fonction de l'angle entre le premier élément de châssis (1) du dispositif électronique portable pour la communication sans fil et le deuxième élément de châssis (2) du dispositif électronique portable pour la communication sans fil.

10. Antenne selon l'une des revendications 8 et 9,
caractérisée en ce que
l'élément de commutation est adapté à commuter entre l'élément de couplage inductif et l'élément de couplage capacitif ou l'élément d'antenne du type PIFA dans un petit intervalle angulaire lors d'un angle défini entre le premier élément de châssis (1) et le deuxième élément de châssis (2).

11. Antenne selon l'une des revendications 8 à 10,
caractérisée en ce que l'élément de commutation (16, 17) est formé par un commutateur capacitif.

12. Antenne selon la revendication 11,
caractérisée en ce que
le commutateur capacitif comprend deux condensateurs variables (16, 17), chaque condensateur variable étant adapté à varier la capacité en fonction de l'angle entre le premier élément de châssis et le deuxième élément de châssis et en face de l'autre condensateur variable respectif.

13. Dispositif électronique portable pour la communication sans fil comprenant une antenne selon l'une des revendications 1 à 12.

FIG 1

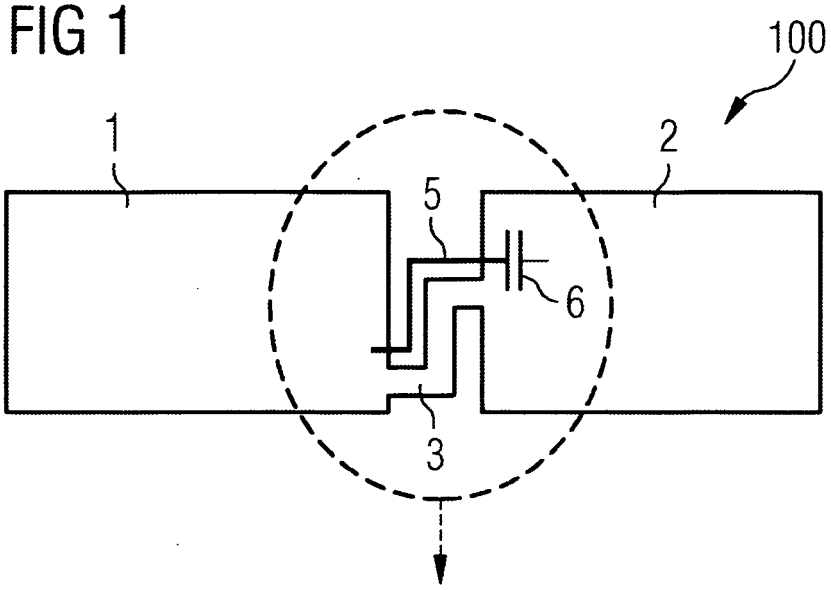


FIG 2

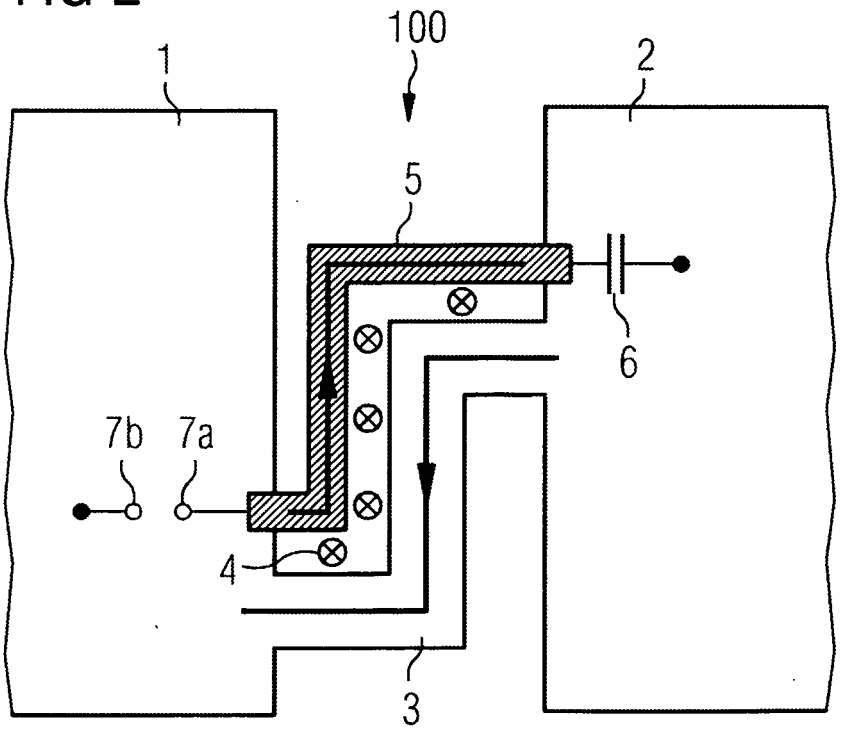


FIG 3

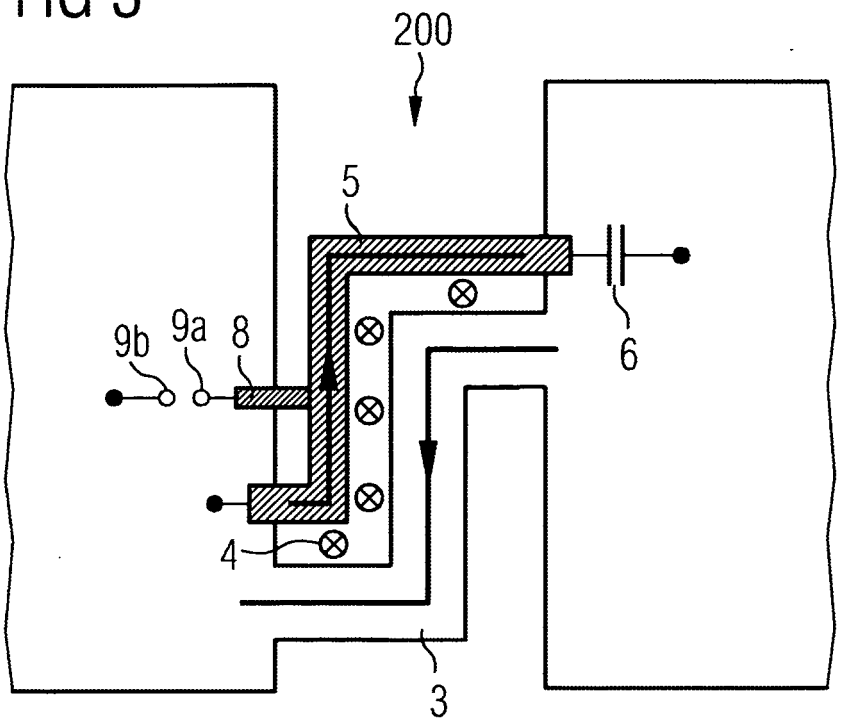


FIG 4

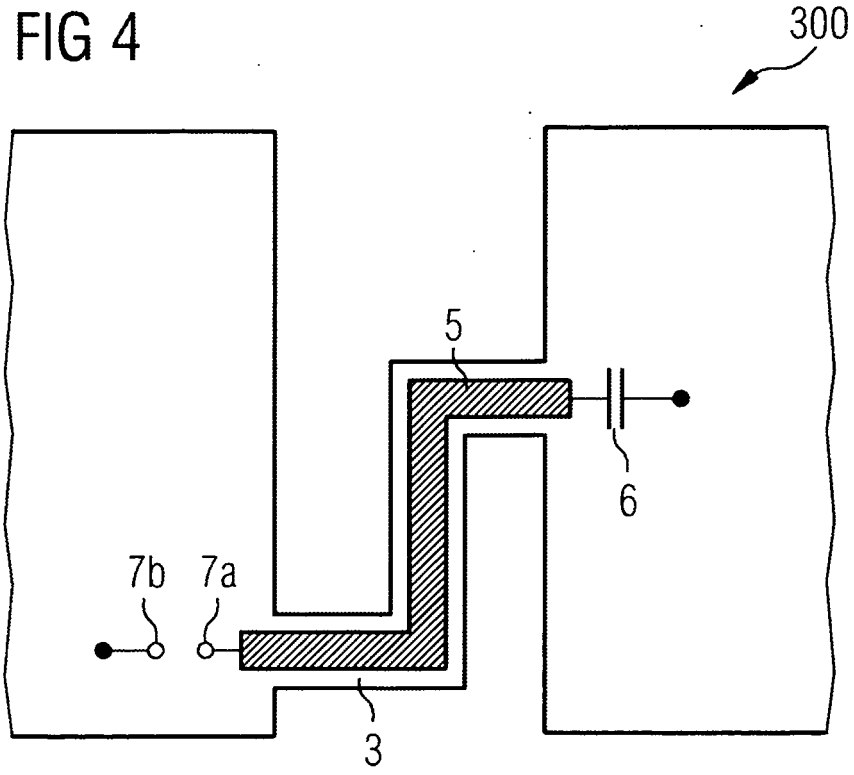


FIG 5

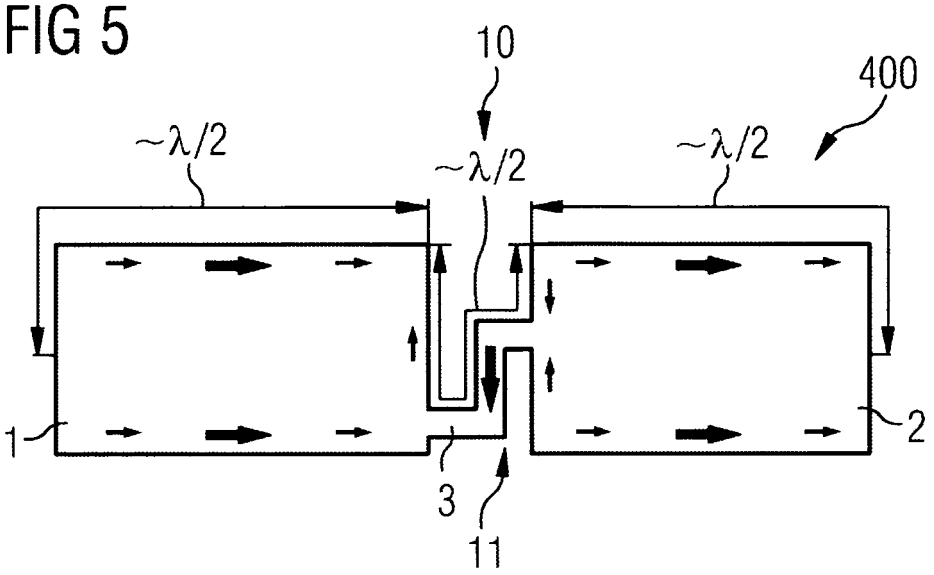


FIG 6

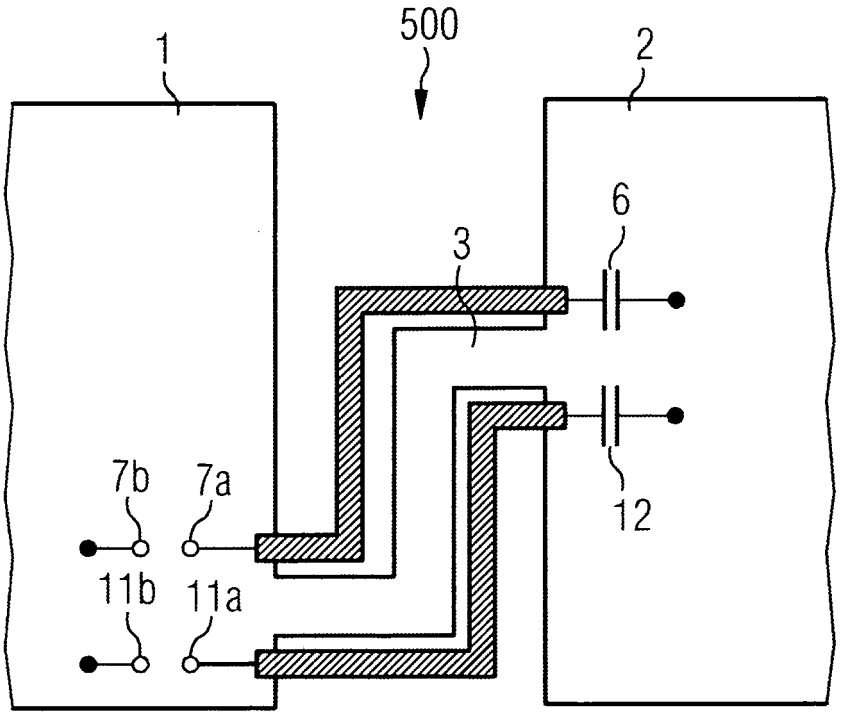


FIG 7

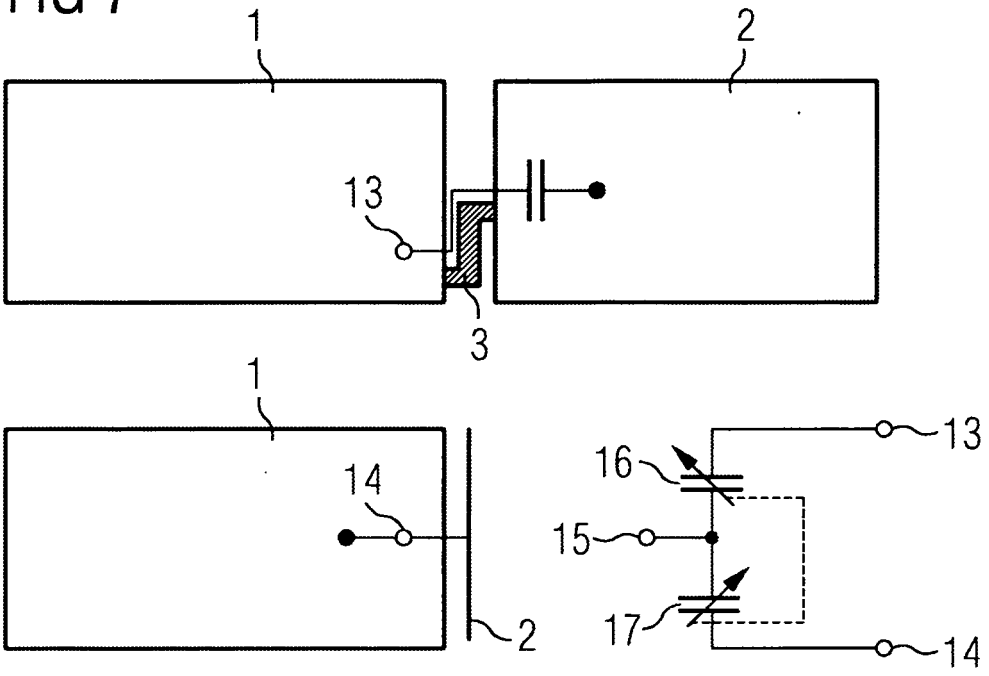


FIG 8

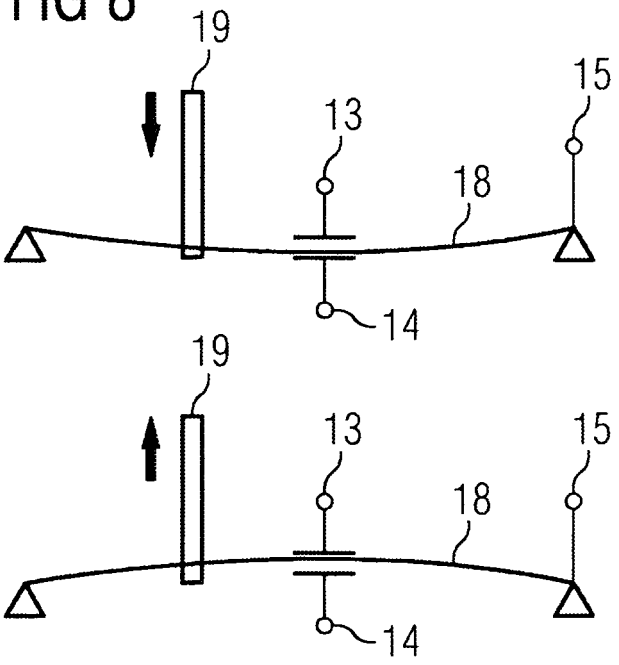


FIG 9

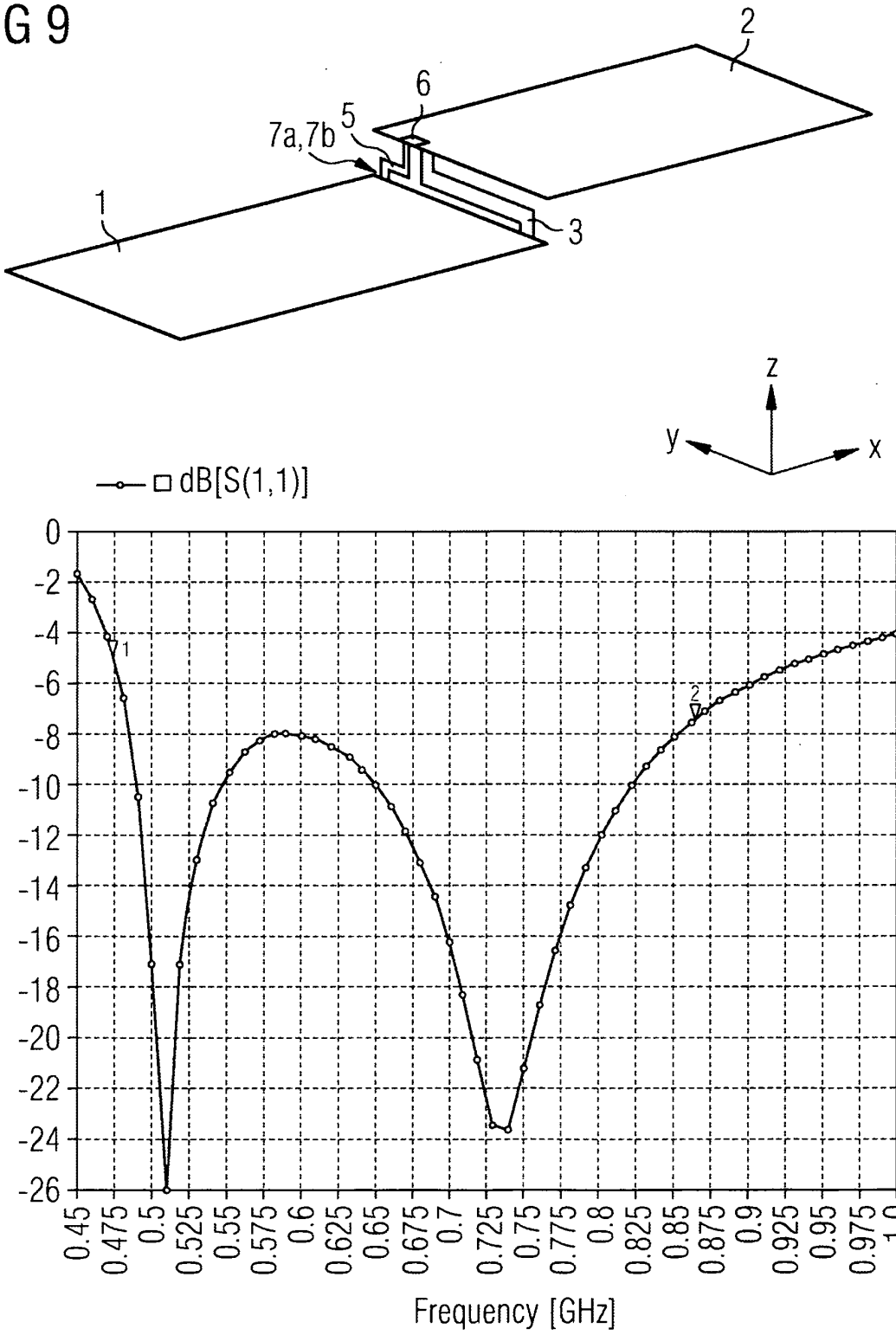

2
6
5
7a,7b
1
3
z
y
x
dB[S(1,1)]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
dB
1
2
0.45
0.475
0.5
0.525
0.55
0.575
0.6
0.625
0.65
0.675
0.7
0.725
0.75
0.775
0.8
0.825
0.85
0.875
0.9
0.925
0.95
0.975
1.0
Frequency [GHz]

FIG 10

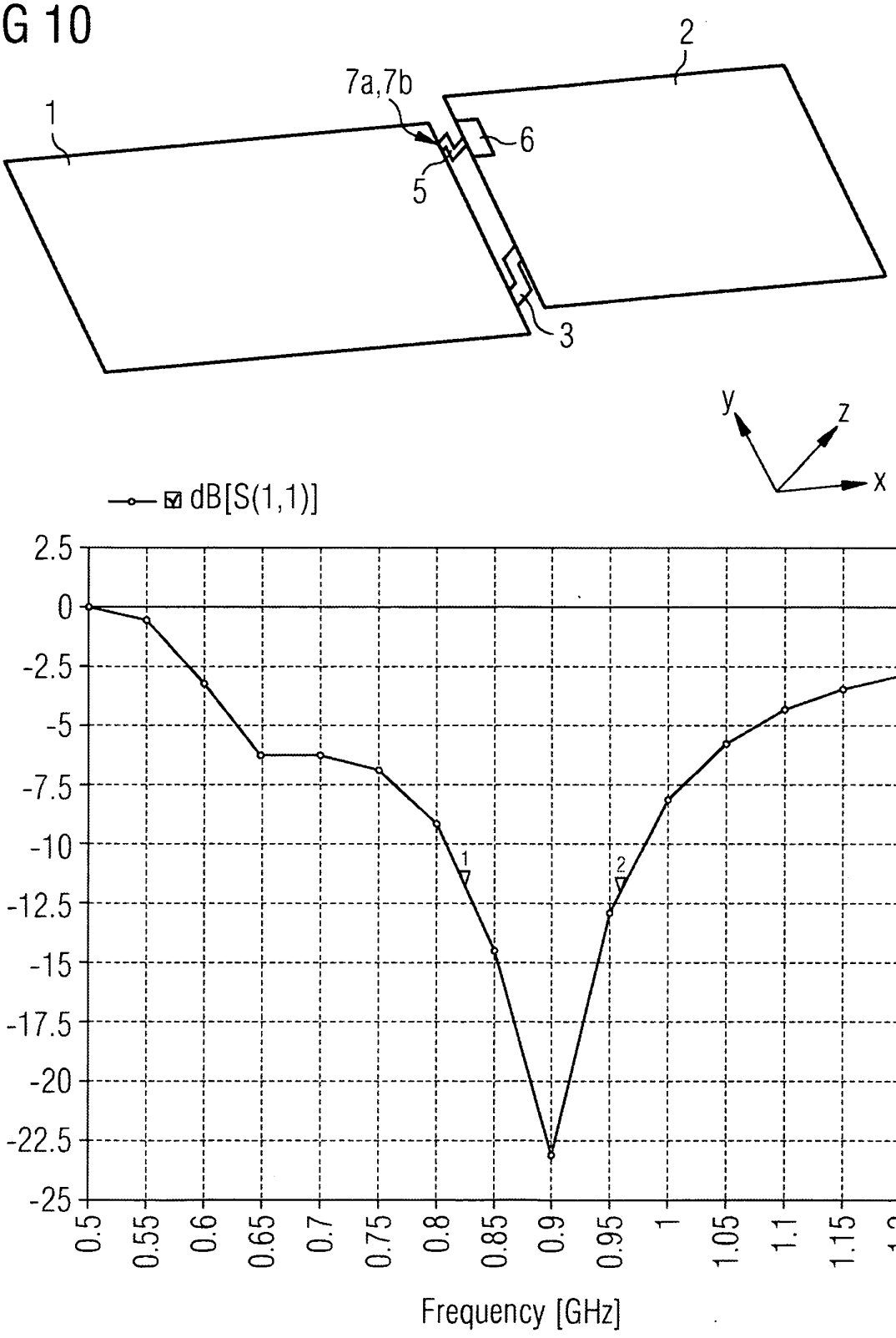

2
7a,7b
1
6
5
3
y
z
x
dB[S(1,1)]
2.5
0
-2.5
-5
-7.5
-10
-12.5
-15
-17.5
-20
-22.5
-25
dB
1
2
0.5
0.55
0.6
0.65
0.7
0.75
0.8
0.85
0.9
0.95
1
1.05
1.1
1.15
1.2
Frequency [GHz]

FIG 11

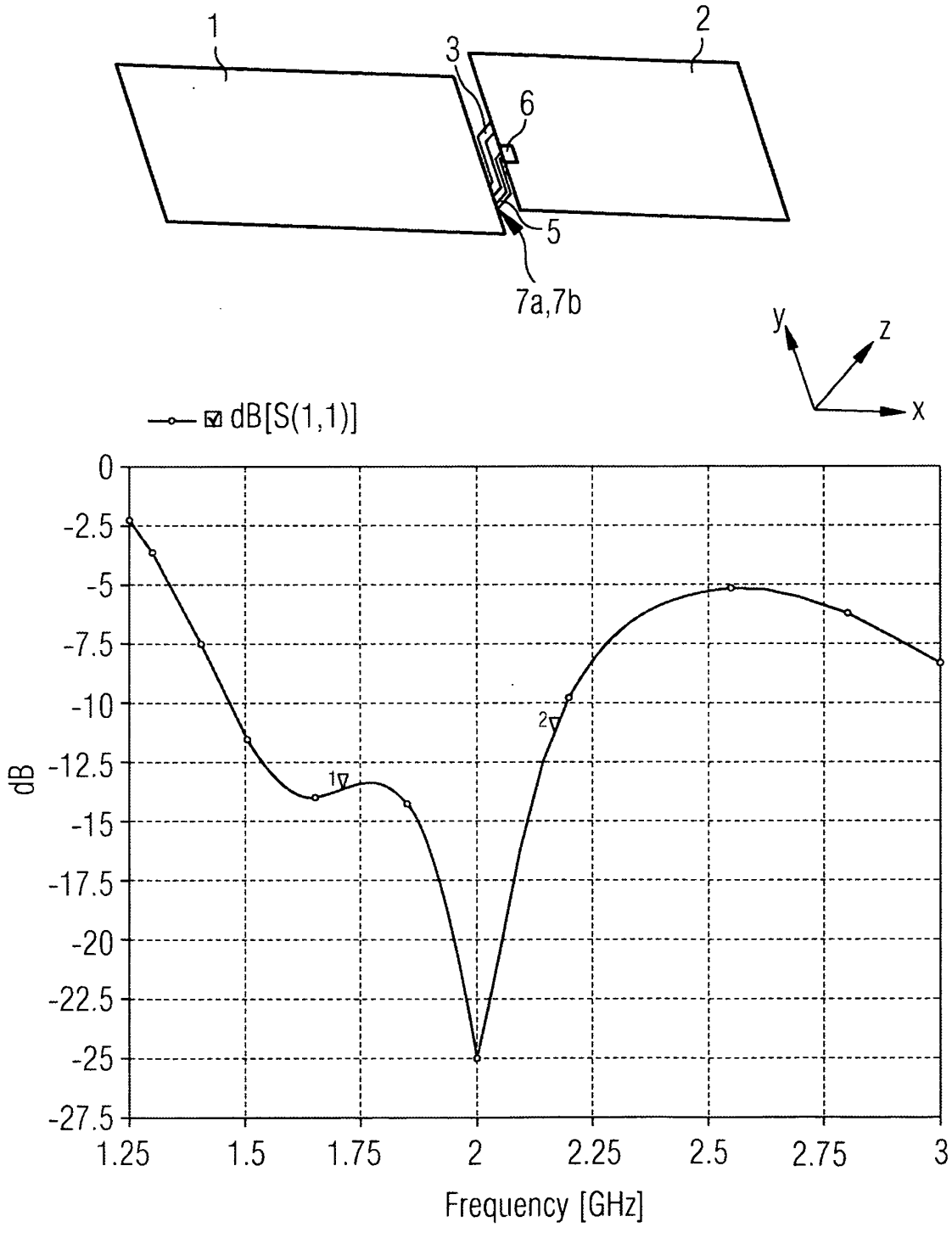
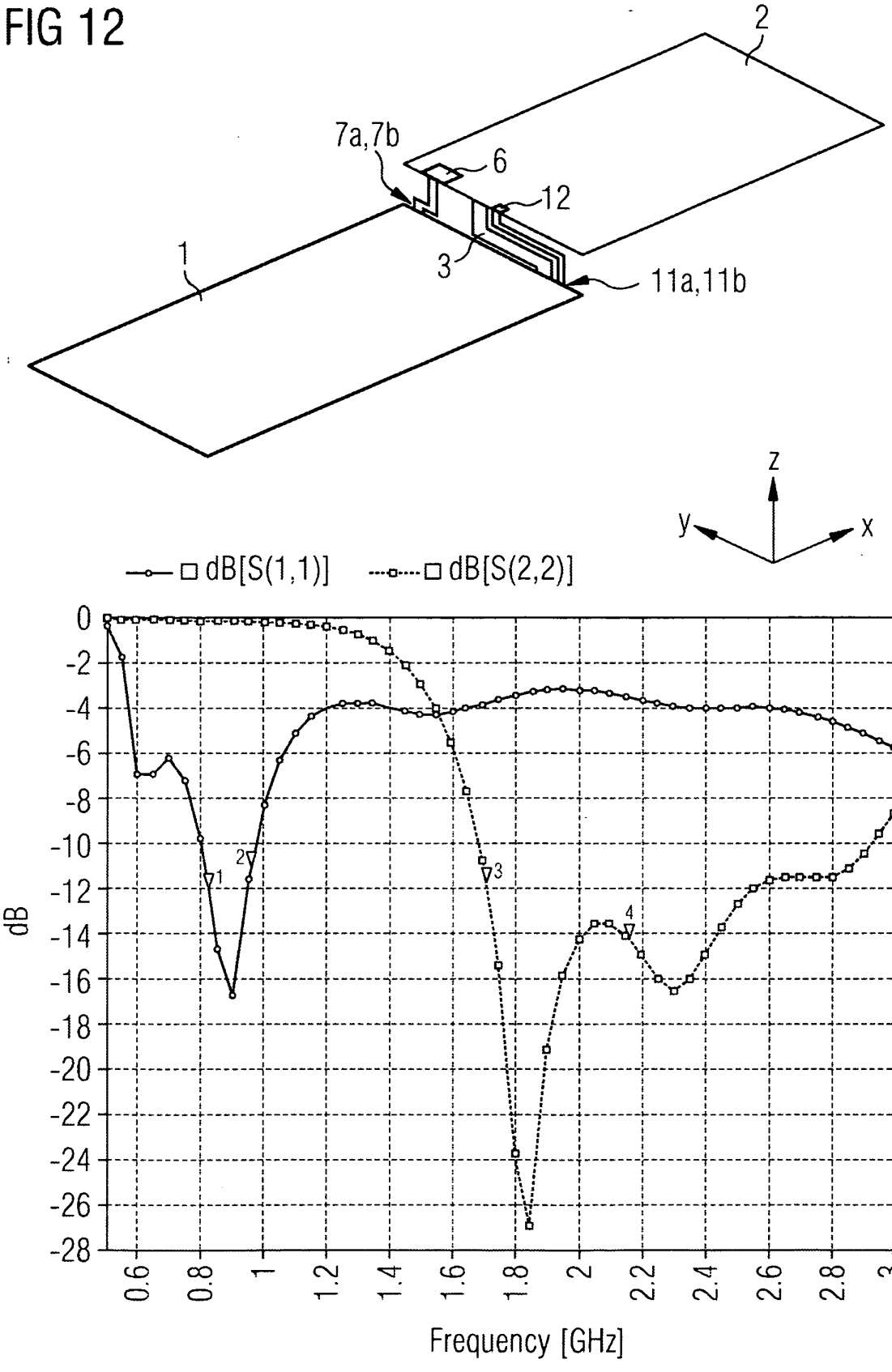

1
2
3
6
5
7a,7b
y
z
x
dB[S(1,1)]
0
-2.5
-5
-7.5
-10
-12.5
-15
-17.5
-20
-22.5
-25
-27.5
dB
1
2
1.25
1.5
1.75
2
2.25
2.5
2.75
3
Frequency [GHz]

FIG 12


2
7a,7b
6
12
1
3
11a,11b
z
y
x
dB[S(1,1)]
dB[S(2,2)]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
dB
1
2
3
4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
Frequency [GHz]

REFERENCES CITED IN THE DESCRIPTION

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