



(11) **EP 1 555 712 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
20.07.2005 Bulletin 2005/29

(51) Int Cl.7: **H01P 1/04, H01P 5/08**

(21) Application number: **04290080.3**

(22) Date of filing: **13.01.2004**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR
HU IE IT LI LU MC NL PT RO SE SI SK TR
Designated Extension States:
AL LT LV MK

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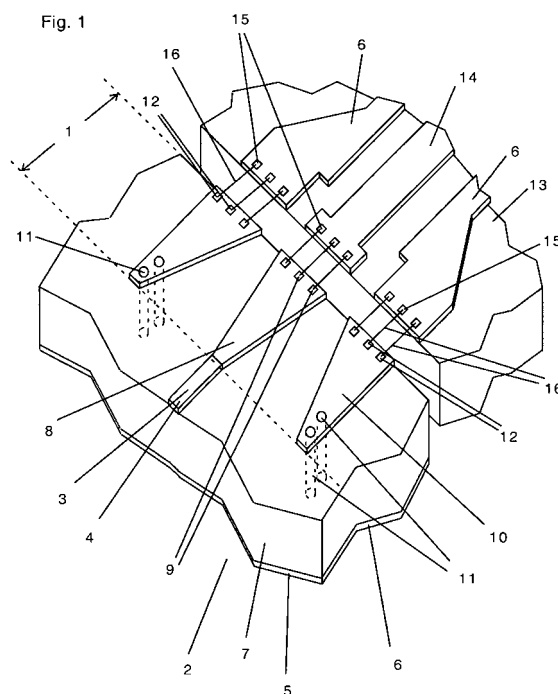
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(54) **High frequency mode converter**

(57) A mode converter (1) is described for being placed in the signal path between two neighboring electronic components (2,13) in order to steadily transform the position of the field lines of a digitalized-data transmitting, high-frequency, broadband electromagnetic signal from an initial position predefined by the arrangement of at least one signal conductor (3,4) in relation to at least one ground conductor (5,6) in the first electronic component (2) to a final position predefined by the relative position of bonding pads (15) arranged at the second electronic component (13), comprising at least one signal-bonding pad (9) placed at the mode converter (1) plus at least one ground-bonding pad (12) placed at the mode converter, wherein the arrangement of the signal-bonding pads (9) and the ground-bonding pads (12) at the mode converter (1) corresponds with the arrangement of the bonding pads (15) at the second electronic component (13), at least one signal waveguide (8) connected with the signal conductor (3,4) and at least one signal-bonding pad (9), at least one ground waveguide (10) connected with at least one ground conductor (5,6) and with at least one ground-bonding pad (12), wherein the clearance between the signal waveguide (8) and the ground waveguide (10) in the area of connection (11) between the ground conductor (5,6) and the ground waveguide (10) is large enough not to allow the signal waveguide (8) and the ground waveguide (10) to exert influence on the position of the field lines of the electromagnetic signal, and wherein the clearance between the signal waveguide (8) and the ground waveguide (10) in the area of connection between the signal waveguide (8) and the signal-bonding pad (9) is small enough that the position of field lines there is only influenced by the relative position of the signal waveguides (8) and the

ground waveguides (10), wherein the clearance between the signal waveguide (8) and the ground waveguide (10) steadily gets smaller from the area of connection (11) of the ground conductor (5,6).



Description

Technical field:

[0001] The invention relates to a mode converter to be placed in the signal path between two neighboring electronic components in order to steadily transform the position of the field lines of a digitalized-data transmitting, high-frequency, broadband electromagnetic signal from an initial position predefined by the arrangement of at least one signal conductor in relation to at least one ground conductor in the first electronic component to a final position predefined by the relative position of bonding pads arranged at the second electronic component, wherein this is achieved by means of a steady reduction of the clearance between at least two waveguides placed in the mode converter, whereby due to the steady reduction of the clearance a resonance-free structure is generated for the high-frequency, electromagnetic signals, which is mandatory to be able to exchange data signals between the two electronic components, plus a method for establishing a bonding-wire connection that allows the transmission of digitalized-data transmitting, high-frequency, broadband, electromagnetic signals between two electronic components by means of equipping at least one of the two electronic components to be connected with each other with at least one mode converter according to one of the Claims 1 to 7 by connecting the signal waveguides and ground waveguides of the mode converter with the signal conductors and ground conductors of the first electronic component and subsequently connecting the signal-bonding pads and the ground-bonding pads of the mode converter with the corresponding bonding pads of the second electronic component by means of bonding wires.

Background of the invention:

[0002] The invention relates to a mode converter according to the specifying features of Claim 1.

[0003] In order to be able to transmit ever growing data volumes by means of digital data transmission technology, it is necessary to use higher and higher frequency ranges for the electromagnetic signals used for the transmission. To be able to clearly identify the digital data transmitted with the help of the electromagnetic signal, i.e. to assign certain values of the electromagnetic signal's amplitude to the digital values '0' and '1', the high-frequency electromagnetic signal also has to be transmitted in a broadband mode, so that a minimum eye-opening is achieved to ensure reliable recognition.

[0004] Especially in complex electronic circuits for generating and evaluating such digitalized-data transmitting, high-frequency, broadband electromagnetic signals, a problem occurs with regard to transmitting the signals from one electronic component, e.g. a circuit board, to another electronic component, e.g. a semicon-

ductor die, as such a high-frequency, broadband signal reacts very sensitively to a manipulation of the position of its field lines, wherein this position is predefined by the arrangement of the respective signal conductor in relation to the related ground conductor.

[0005] In the case of a conventionally structured circuit board that has a ground plane placed under a dielectric, the position of the field lines may be predefined by, for example, a microstrip placed above the dielectric and the ground plane placed below the dielectric. Accordingly, in the case of shielded microstrips, triplates resp. striplines, suspended substrates, coplanar microstrips and the like, a characteristic field line structure can be found. The way the signal conductor and the ground conductor are arranged is primarily determined by manufacturing aspects. Microstrips with a ground plane, for example, are much easier to produce than coplanar microstrips.

[0006] Likewise, on semiconductor dies the position of the field lines is predefined by the arrangement of the signal conductors in relation to the ground conductors. The arrangement of the signal conductors in relation to the ground conductors is subject to certain limitations, resulting from the semiconductor material used for the semiconductor die. For example, in the case of Si-dies (because of the conductivity of the doped silicon) or InP-dies, a coplanar arrangement of the signal conductors and the ground conductors is mandatory, whereas in the case of Si-CMOS-dies and GaAs-dies both a coplanar arrangement of the signal conductors and the ground conductors and a microstrip structure is possible, the latter bringing about reduced speed, however.

[0007] As a consequence, semiconductor dies are usually equipped with coplanar structures due to performance reasons, while circuit boards usually have microstrip structures due to production reasons. The problem is that both structures need to be connected with each other.

[0008] Currently, such electronic components are being connected by means of a technique developed for the exchange of low-frequency or narrowband signals between electronic components, i.e. by using bond pads at both components and by directly connecting the respective bond pads by means of bond wires, wherein the bond pads are connected directly to the ends of the corresponding conduits without taking into account a certain arrangement.

[0009] Beyond 10 GHz, such conventional structures are limited in usefulness, primarily because of parasitic inductance effects which result in severe impedance mismatch loss and the loss of the necessary eye-opening of the electromagnetic signal to be transmitted. A high-frequency transition is required to efficiently couple, for example, the microstrip transmission line of a circuit board and the coplanar waveguide on a semiconductor die at frequencies beyond 10 GHz.

[0010] The electromagnetic signals necessary for digital data transmission, however, lie in a frequency range

from 100 to 1000 GHz.

[0011] As is known from US 5,583,468, in order to inject a high-frequency amplifier signal from a microstrip circuit board into a semiconductor die with a coplanar arrangement of conductors, a mode converter can be placed on the microstrip circuit board, wherein the described mode converter has a resonant structure for electromagnetic signals with areas of different impedance, whereby the field lines of the electromagnetic signal are being transformed abruptly from their initial position predefined by the microstrip circuit board to the final position necessary for achieving transmission to the semiconductor die by means of bond wires.

[0012] For the transmission of digitalized-data transmitting, high-frequency, broadband electromagnetic signals, such a resonant structure is improper, since due to resonances and pertinent effects the minimum eye-opening cannot be maintained.

Technical purpose of the invention:

[0013] The technical purpose of the invention is to develop a mode converter that allows to steadily transform the field lines of a digitalized-data transmitting, high-frequency, broadband electromagnetic signal from an initial position predefined by one electronic component to a final position predefined by another electronic component, without affecting the digital data transmission minimum eye-opening, and to develop a method for connecting two electronic components between which digitalized-data transmitting, high-frequency, broadband electromagnetic signals are to be exchanged.

Disclosure of the invention and its advantages:

[0014] The first part of the invention's technical purpose is fully met by said mode converter of said specifying features of Claim 1, wherein the mode converter is characterized by at least one signal-bonding pad placed at the mode converter for connection with at least one corresponding bonding pad at the second electronic component by means of at least one bonding wire for signal transmission, plus at least one ground-bonding-pad placed at the mode converter for connection with at least one corresponding bonding pad at the second electronic component by means of at least one bonding wire for ground transmission, wherein the arrangement of the signal-bonding pads and the ground-bonding pads at the mode converter corresponds with the arrangement of the bonding pads at the second electronic component, at least one signal waveguide connected with the signal conductor and with at least one signal-bonding pad, and at least one ground waveguide connected with at least one ground conductor and with at least one ground-bonding pad, wherein the clearance between the signal waveguide and the ground waveguide in the area of connection between the ground conductor and the ground waveguide is large

enough not to allow the signal waveguide and the ground waveguide to exert influence on the position of the field lines of the electromagnetic signal, and wherein the clearance between the signal waveguide and the ground waveguide in the area of connection between the signal waveguide and the signal-bonding pad is small enough that the position of field lines there is only influenced by the relative position of the signal waveguides and the ground waveguides, wherein the clearance between the signal waveguide and the ground waveguide steadily gets smaller from the area of connection of the ground conductor and the ground waveguide to the area of connection of the signal waveguide and the signal-bonding pad, so that the waveguides of the mode converter represent a resonance-free structure for the high-frequency, broadband, electromagnetic signal to be transmitted, wherein the first electronic component and the second electronic component are electrically connected by means of bonding wires placed between the signal-bonding pads and the ground-bonding pads of the mode converter and the corresponding bonding pads of the second electronic component. The first electronic component may be both a circuit board and a semiconductor die. The same applies to the second electronic component. The reduction of the clearance between the signal waveguide and the ground waveguide along the signal transmission path from the first electronic component to the signal-bonding pads and the ground-bonding pads of the mode converter does not have to be linear but can be parabolic, hyperbolic or according to an E-function, for example. The core of the invention is that no abrupt change in the clearance and hence no discontinuities occur along the signal transmission path between the signal waveguide and the ground waveguide, whereby the formation of a resonator in the mode converter is prevented, so that data transmission through the mode converter is made possible. The direction of the signal transmission is not predetermined, i.e. data transmission can also take place vice versa, from the signal-bonding pads and ground-bonding-pads to the first electronic component.

[0015] In a preferred embodiment of said mode converter, instead of or in addition to the change in the clearance between the signal waveguides and the ground waveguides, the breadth and/or the thickness of the signal waveguides and/or the ground waveguides are steadily becoming smaller or larger from the area of connection of the ground conductor and the ground waveguide to the area of connection of the signal waveguide and the signal-bonding pad.

[0016] In a preferred embodiment of said mode converter, the mode converter is an integral part of one of the two electronic components to be connected with each other.

[0017] In another preferred embodiment of said mode converter, one electronic component is a circuit board and the other electronic component is a semiconductor

die that has a coplanar arrangement of conductors and coplanarly arranged bonding pads, wherein the signal conductor is a microstrip placed on the upside of the circuit board and the ground conductor is a ground plane placed on the bottom side of the circuit board and the ground-bonding pads and the signal-bonding pads of the mode converter are arranged coplanarly, wherein the signal waveguide is connected with the microstrip and a ground waveguide is placed on the upside of the circuit board on both sides of the signal waveguide for being connected with the ground plane by means of at least one interlayer connection, and the clearance along the signal transmission path between the ground waveguides placed on both sides of the signal waveguide and this signal waveguide steadily gets smaller from a cross section orthogonal to the microstrip in the area of the interlayer connection to a cross section orthogonal to the microstrip in the area of the ground-bonding pads and the signal-bonding pads.

[0018] In another preferred embodiment of said mode converter, the ground-bonding pads and the signal-bonding pads and the ground waveguides and the signal waveguides of the mode converter are arranged coplanarly on the upside of the circuit board together with the microstrip, wherein the steady transformation of the field lines is achieved by a steady reduction of the clearance between the ground waveguides placed on both sides of the signal waveguide and this signal waveguide and/or a steady increase or decrease of the thickness and the breadth of the ground waveguides and/or the signal waveguides.

[0019] In an additional preferred embodiment of said mode converter, the mode converter is frontally connected with a circuit board. The position of the field lines of the electromagnetic signal may also be manipulated by a steady twisting of the signal waveguides and the ground waveguides around the longitudinal axis of the signal conductor along the signal path.

[0020] In a particularly preferred embodiment of said mode converter, one of the two electronic components is a triplate circuit board with a stripline accommodated between two ground planes.

[0021] The second part of the invention's technical purpose is fully met by said method for establishing a bonding-wire connection between two electronic components (according to the specifying features of Claim 7) that allows the transmission of digitalized-data transmitting, high-frequency, broadband electromagnetic signals, which is characterized by the connection of at least one mode converter according to one of the previous claims at or on at least one of the two electronic components to be connected with each other by connecting the signal waveguides and the ground waveguides of the mode converter with the signal conductors and ground conductors of the first electronic component and subsequently connecting the signal-bonding pads and the ground-bonding pads of the mode converter with the corresponding bonding pads of the

second electronic component by means of bonding wires.

Paths for performing the invention:

[0022] A mode converter 1 as shown in Figure 1 is mounted on the upside of a circuit board 2, where a signal conductor 4, in the form of a microstrip 3, leads to the mode converter 1. On the bottom side of the circuit board 2, a ground conductor 6 is mounted in the form of a ground plane 5. Between the ground plane 5 and the microstrip 3, the circuit board 2 consists of a dielectric 7, which insulates the ground plane 5 and the microstrip 3 against each other.

[0023] The mode converter 1 consists of a signal waveguide 8, which on one end is connected with the microstrip 3 and which on the other end has three signal-bonding pads 9 mounted, and two ground waveguides 10 placed on both sides of the signal waveguide 8. By means of an interlayer connection 11, the ground waveguides 10 are connected with the ground plane 5 roughly in the same cross section orthogonal to the microstrip 3 the signal waveguide 8 is connected with the microstrip 3, with the ground waveguides 10 ends averted from the interlayer connection 11 each being equipped with three ground-bonding pads 12.

[0024] The arrangement of the signal-bonding pads 9 and the ground-bonding pads 12 in relation to one another corresponds with the corresponding bonding pads 15 at a semiconductor die 13.

[0025] In the same cross section orthogonal to the microstrip 3 the signal waveguide 8 is connected with the microstrip 3, the clearance between the ground waveguides 10 and the signal waveguides 8 is large enough that the position of the field lines of a digitalized-data transmitting, high-frequency, broadband electromagnetic signal to be transmitted from the microstrip 3 placed on the circuit board 2 to a signal conductor 14 placed on a semiconductor die 13 is determined only by the microstrip 3 and the ground plane 5. The closer the signal approaches the signal-bonding pads 9 and the ground-bonding pads 12, the more the position of the signal's field lines is influenced by the steady reduction of the clearance between the ground waveguides 10 and the signal waveguide 8, whereby the field lines are being transformed from an initial position predefined by the microstrip 3 and the ground plane 5 to a final position predefined by the arrangement of the bonding pads 15 of the semiconductor die 13. The signal-bonding pads 9 and the ground-bonding pads 12 of the mode converter 1 are each being connected with the corresponding bonding pads 15 of the semiconductor die 13 by means of a bonding wire 16. By the steady reduction of the clearance between the ground waveguides 10 and the signal waveguide 8, the field lines are being steadily transformed from the initial position into the final position. The formation of a resonant structure of the electromagnetic signals is thereby prevented, which is a pre-

requisite to ensure the transmission of digital data by means of these signals.

Commercial applicability:

[0026] The invention is commercially applicable particularly in the field of production of electronic circuits for generating or evaluating digitalized-data transmitting, high-frequency, broadband electromagnetic signals.

List of reference numerals:

[0027]

- 1 mode converter
- 2 circuit board
- 3 microstrip
- 4 signal conductor
- 5 ground plane
- 6 ground conductor
- 7 dielectric
- 8 signal waveguide
- 9 signal-bonding pad
- 10 ground waveguide
- 11 interlayer connection
- 12 ground-bonding pad
- 13 semiconductor die
- 14 signal conductor
- 15 bonding pad
- 16 bonding wire

Claims

1. Mode converter to be placed in the signal path between two neighboring electronic components in order to steadily transform the position of the field lines of a digitalized-data transmitting, high-frequency, broadband electromagnetic signal from an initial position predefined by the arrangement of at least one signal conductor in relation to at least one ground conductor in the first electronic component to a final position predefined by the relative position of bonding pads arranged at the second electronic component, **characterized in that** at least one signal-bonding pad (9) is placed at the mode converter (1) plus at least one ground-bonding pad (12) is placed at the mode converter, wherein the arrangement of the signal-bonding pads (9) and the ground-bonding pads (12) at the mode converter (1) corresponds with the arrangement of the bonding pads (15) at the second electronic component (13), at least one signal waveguide (8) is connected with the signal conductor (3, 4) and at least one signal-bonding pad (9), at least one ground waveguide (10) is connected with at least one ground conductor (5, 6) and with at least one ground-bonding pad (12), wherein the clearance

between the signal waveguide (8) and the ground waveguide (10) in the area of connection (11) between the ground conductor (5, 6) and the ground waveguide (10) is large enough not to allow the signal waveguide (8) and the ground waveguide (10) to exert influence on the position of the field lines of the electromagnetic signal, and wherein the clearance between the signal waveguide (8) and the ground waveguide (10) in the area of connection between the signal waveguide (8) and the signal-bonding pad (9) is small enough that the position of field lines there is only influenced by the relative position of the signal waveguides (8) and the ground waveguides (10), wherein the clearance between the signal waveguide (8) and the ground waveguide (10) steadily gets smaller from the area of connection (11) of the ground conductor (5, 6) and the ground waveguide (10) to the area of connection of the signal waveguide (8) and the signal-bonding pad (9).

2. Mode converter according to Claim 1, **characterized in that** instead of or in addition to the change in the clearance between the signal waveguides (8) and the ground waveguides (10), the breadth and/or the thickness of the signal waveguides (8) and/or the ground waveguides (10) is steadily becoming smaller or larger from the area of connection (11) of the ground conductor (5, 6) and the ground waveguide (10) to the area of connection of the signal waveguide (8) and the signal-bonding pad (9).
3. Mode converter according to Claim 1 or 2, **characterized in that** the mode converter (1) is an integral part of one of the two electronic components (2, 13) to be connected with each other.
4. Mode converter according to Claim 1, 2 or 3, **characterized in that** one electronic component is a circuit board (2) and the other electronic component is a semiconductor die (13) that has a coplanar arrangement of conductors and coplanarly arranged bonding pads (15), wherein the signal conductor (3, 4) is a microstrip (3) placed on the upside of the circuit board (2) and the ground conductor (5, 6) is a ground plane (5) placed on the bottom side of the circuit board (2), and wherein the ground-bonding pads (12) and the signal-bonding pads (9) of the mode converter (1) are arranged coplanarly, wherein the signal waveguide (8) is connected with the microstrip (3) and a ground waveguide (10) is placed on the upside of the circuit board (2) on both sides of the signal waveguide (8) for being connected with the ground plane (5) by means of at least one interlayer connection (11), and the clearance along the signal

transmission path between the ground waveguides (10) placed on both sides of the signal waveguide (8) and this signal waveguide (8) steadily gets smaller from a cross section orthogonal to the microstrip (3) in the area of the interlayer connection (11) to a cross section orthogonal to the microstrip (3) in the area of the ground-bonding pads (12) and the signal-bonding pads (9). 5

5. Mode converter according to Claim 4, **characterized in that** 10

the ground-bonding pads (12) and the signal-bonding pads (9) and the ground waveguides (10) and the signal waveguides (8) of the mode converter (1) are arranged coplanarly on the upside of the circuit board (2) together with the microstrip (3). 15

6. Mode converter according to Claim 4, **characterized in that** 20

the mode converter (1) is frontally connected with a circuit board (2).

7. Mode converter according to Claim 1, 2 or 3, **characterized in that** 25

one of the two electronic components (2, 13) is a triplate circuit board with a stripline accommodated between two ground planes (5).

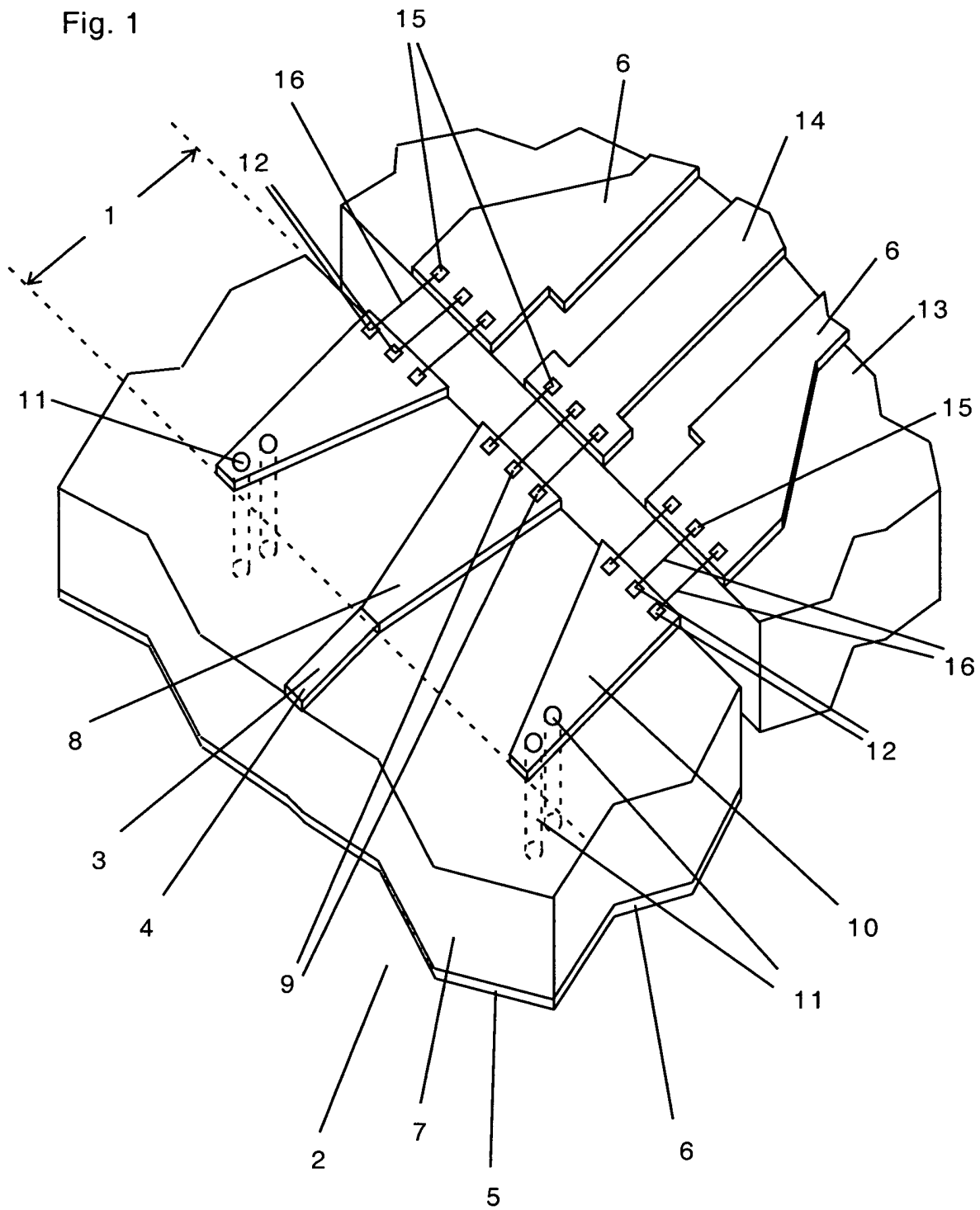
8. Method for establishing a bonding-wire connection between two electronic components that allows the transmission of digitalized-data transmitting, high-frequency, broadband electromagnetic signals **characterized by** 30

the connection of at least one mode converter (1) according to one of the previous claims at or on at least one of the two electronic components (2, 13) to be connected with each other by connecting the signal waveguides (8) and the ground waveguides (10) of the mode converter (1) with the signal conductors (3, 4) and the ground conductors (5, 6) of the first electronic component (2) and subsequently connecting the signal-bonding pads (9) and the ground-bonding pads (12) of the mode converter (1) with the corresponding bonding pads (15) of the second electronic component (13) by means of bonding wires (16). 35 40 45

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Fig. 1





European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 04 29 0080

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			H01P
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 13 April 2004	Examiner Den Otter, A
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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