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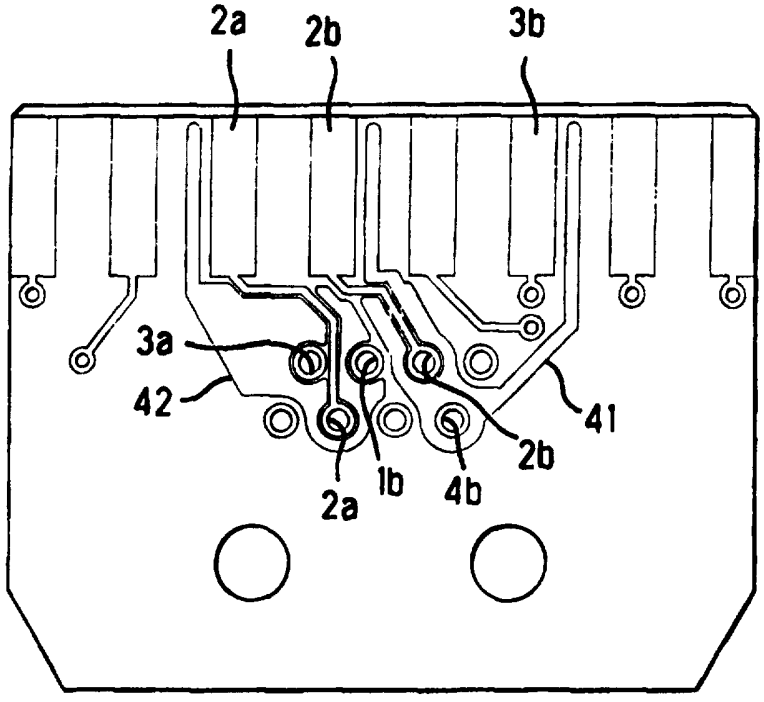
(57) Abstract

Cross talk is reduced in a communications wiring system by an arrangement of circuit traces on a circuit board (10). The circuit board has circuit traces which are arranged for interconnecting terminals in first and second electrical connectors (12, 14), wherein the terminals in each connector are associated as signal pairs in the communications wiring system. The circuit board also has at least one trace (41) which is not ohmically connected to any of the circuit traces on the board. The non-ohmically connected trace is arranged closely adjacent to at least two of the circuit traces interconnecting different signal pairs so as to couple energy therebetween, whereby cross talk between the at least two circuit traces is reduced.



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NON-OHMIC ENERGY COUPLING FOR CROSSTALK REDUCTION

The invention relates to an electrical device which promotes energy coupling between signal paths in a high speed data communications system in order to reduce crosstalk between the signal paths.

Due to increases in data transmission rates in telecommunications systems, crosstalk has become a significant problem. Crosstalk may be defined as stray energy which is coupled from one signal line onto an adjacent signal line by either capacitive or inductive coupling. This crosstalk results in signal noise which interferes with the purity of the signal being transmitted.

A commonly used telecommunications wiring system is unshielded twisted pair wiring wherein pairs of wires are twisted about each other. The wires in a twisted pair carry related signals and are thus known as signal pairs.

Crosstalk in unshielded twisted pair wiring systems primarily arises in the electrical connectors which provide an interface between successive runs of cable in a system. The connectors such as modular jacks are commonly mounted on a circuit board which interconnects through a card edge connector to the wiring system. The circuit board carries circuit lines or traces which extend between one set of terminals on the board which are matable with the modular jack, and another set of terminals on the board which are matable with the card edge connector.

Prior art techniques for reducing crosstalk include arrangements of the circuit traces on the board in such a manner that energy coupling in adjacent traces will cancel the effects of energy coupling which occurs in the modular plug and jack. U.S. Patent No. 5,299,956 discloses an arrangement wherein the traces on the board are routed in a pattern that is opposite in polarity to

the pattern that produces crosstalk in the plug and jack. However, it has been found that this technique results in higher structural return loss because of the impedance mismatch between the connector system and the cable.

U.S. Patent No. 5,310,363 discloses a crosstalk reduction method which avoids the higher return loss. The technique involves adding an additional trace to the board. The additional trace interconnects two of the same terminals which are interconnected by one of the other traces. Thus, two of the traces each carry an identical signal. These traces are routed so that the signal on one trace provides proper pair balance and impedance, and the signal on the other trace provides increased coupling with a trace in one of the other pairs for crosstalk reduction.

It is now proposed to reduce crosstalk by providing an additional trace which is not ohmically connected to any of the other traces. The non-ohmically connected trace is routed closely adjacent to portions of two or more traces in different signal pairs, thereby coupling energy from each trace to the other so that crosstalk is reduced.

The invention is a circuit board for interconnecting a first electrical connector with a second electrical connector, wherein the first electrical connector has a set of closely spaced terminals each being associated with a respective other one of the terminals to form a signal pair, and each of the signal pairs are associated with a respective electrical circuit through the connector, whereby adjacent ones of the terminals in different said signal pairs are susceptible to electrical crosstalk. The circuit board comprises a dielectric substrate having circuit traces thereon which are arranged for electrically interconnecting the first set of terminals with a corresponding set of terminals in the second

electrical connector. The circuit board has at least one other trace which is not ohmically connected to any of the circuit traces. The non-ohmically connected trace is arranged for coupling energy between two of the circuit traces which are in different ones of the pairs, whereby crosstalk between the two circuit traces is reduced. In one embodiment the non-ohmically connected trace is disposed on the substrate and extends closely adjacent to each of the two circuit traces for at least a portion of the respective length of each circuit trace.

The invention will now be described by way of example with reference to the accompanying drawings in which:

Fig. 1 is an exploded isometric view of a pair of exemplary electrical connectors which can be interconnected by a circuit board according to the invention;

Fig. 2 is a schematic representation of parallel conductors in a four pair wiring system;

Figs. 3 and 4 are plan views of respective opposite sides of a circuit board with which the invention can be used;

Figs. 5-9 are separate plan views of the circuit board each having an individual non-ohmically connected trace according to the invention; and

Figs. 10 and 11 are plan views of opposite sides of the circuit board having the non-ohmically connected traces combined thereon.

There is shown in Fig. 1 an exemplary RJ45 modular jack 12 and an edge connector 14 which can be interconnected by a circuit board 10 according to the invention. The modular jack 12 has eight terminals 16 corresponding to respective signal lines in a four pair communications wiring system. The terminals 16 are arranged in an industry standard footprint for engagement in plated through-holes or vias 24 in the

circuit board 10. Alternatively, the terminals 16 may be formed with surface mount feet for mating engagement with respective surface mount pads on the circuit board.

The circuit board 10 has lines of conductive material which extend from the plated through-holes 24 to respective pads 32 along an edge of the board. Each line of conductive material along with its respective plated through-hole 24 and pad 32 comprises a respective circuit trace or signal trace 26. The board edge having the pads 32 thereon is receivable in a cavity 17 of the edge connector 14 for engagement with corresponding terminals therein.

The terminals 16 extend within the modular jack in a side-by-side parallel arrangement for engagement with mating terminals of a modular plug (not shown) which is insertable in cavity 18 of the modular jack. Significant crosstalk can occur within the modular plug and the modular jack due to the terminals in different signal pairs being in close proximity and parallel to each other.

The eight terminals within the modular jack are dedicated to specific signal lines in the communications wiring system. Fig. 2 illustrates schematically the arrangement of the terminals according to industry standards. The terminals are arranged in four signal pairs with the first signal pair 1a-ab being a central pair, the second pair 2a-2b straddling the first pair, and the third and fourth pairs 3a-3b and 4a-4b being at respective opposite ends of the row. Crosstalk occurs mostly between adjacent signal lines in different pairs. For example, lines 3b-2a, 2a-1a, 1b-2b, and 2b-4a are all crosstalking pairs. Crosstalk is greatest in the crosstalking pairs which are formed by one signal pair which straddles another signal pair, that is, in the crosstalking pairs 2a-1a and 1b-2b.

Although crosstalk may occur between the terminals of different signal pairs in the edge connector 14, it

has been found that near end crosstalk (NEXT) which occurs in the modular plug and jack is significantly greater than far end crosstalk which occurs in the edge connector.

Crosstalk can be reduced in a communications wiring system by coupling energy between non-crosstalking signal lines in order to cancel the effects of energy coupling in the crosstalking lines. According to the invention, one or more additional traces are provided on the circuit board in order to accomplish energy coupling. These traces are not ohmically connected to any of the signal traces 26. Instead, the non-ohmic traces are arranged closely adjacent to the signal traces in order to promote energy coupling through the effects of capacitance and inductance.

With reference to Fig. 5, according to the invention a first non-ohmically connected trace 41 on the circuit board is arranged closely adjacent to the signal traces corresponding to signal lines 2b, 3b and 4b. As shown, the first non-ohmically connected trace extends along a side of the pad 3b, surrounds the through-hole 4b, partially surrounds the through-hole 2b, extends along both sides of the trace 2b and extends along a side of the pad 2b. By referring back to Fig. 2, it can be seen that signal line 4a generates crosstalk in line 2b. The first non-ohmic trace 41 couples energy between lines 2b and 4b, thereby cancelling the crosstalk generated by line 4a. The trace 41 also couples energy between lines 2b and 3b, thereby cancelling the crosstalk generated in line 3b by line 2a.

Referring now to Fig. 6, a second non-ohmically connected trace 42 is arranged closely adjacent to the signal traces corresponding to signal lines 1b, 2a and 3a. The second non-ohmic trace extends alongside the pad 2a, and substantially surrounds the through-holes 3a, 2a and 1b. This arrangement cancels the effects of

crosstalk induced in signal line 3b by line 2a, and cancels the effects of crosstalk induced in signal line 2a by line 1a.

Fig.7 shows a third non-ohmic trace 43 arranged closely adjacent to the signal traces corresponding to signal lines 1a and 2b. The non-ohmic trace 43 compensates for crosstalk induced in line 1a by line 2a.

Fig.8 shows a fourth non-ohmic trace 44 arranged closely adjacent to the signal traces corresponding to lines 2b and 4b. The non-ohmic trace 44 compensates for crosstalk induced in line 2b by line 4a.

Fig. 9 shows a fifth non-ohmic trace 45 arranged closely adjacent to the traces corresponding to lines 1b and 2a. The non-ohmic trace 45 compensates for crosstalk induced in line 2a by line 1a.

Non-ohmic traces according to the invention can be provided either singly as shown in the Figs. 5-9, or in some combination such as by combining all of the individual non-ohmic traces on one circuit board as shown in Figs. 10 and 11. The non-ohmic traces are selectively arranged according to the layout of signal traces on the circuit board. The precise configuration and arrangement of the non-ohmic traces is influenced by the layout of signal traces on the board and the crosstalk characteristics of the communications wiring system. As shown in the drawings, the non-ohmic traces are more effectively configured as broad areas of conductive material rather than narrow conductive lines, in order to increase the capacitive effect of the non-ohmic traces.

An important advantage of the present invention is that crosstalk can be reduced while maintaining a constant spacing between circuit traces of a signal pair. As shown in Fig. 10, traces 1a and 1b of one signal pair are routed along a parallel course on the circuit board with a constant spacing between them. This constant spacing benefits impedance matching

between the traces. In contrast, the prior art methods of crosstalk reduction utilize an increased separation between the traces, or utilize signal traces with additional branches which provide capacitive coupling therebetween, and both of these methods result in an impedance mismatch which is detrimental to overall performance.

Due to the imprecise nature of crosstalk cancellation through energy coupling, it should be apparent to those skilled in the art that a great variety of effective non-ohmic trace configurations can be provided. Accordingly, the precise configurations and arrangements shown in the drawings are intended only to be illustrative and not limiting, and reference should be made to the appended claims in order to assess the scope of the invention in which exclusive rights are claimed.

CLAIMS

1. A circuit board (10) for interconnecting a first electrical connector (12) with a second electrical connector (14), the first electrical connector having a set of closely spaced terminals each being associated with a respective other one of the terminals to form a signal pair, each of the signal pairs being associated with a respective electrical circuit through the connector, whereby adjacent ones of the terminals in different said signal pairs are susceptible to electrical crosstalk, the circuit board comprising a dielectric substrate having circuit traces thereon which are arranged for electrically interconnecting the first set of terminals with a corresponding set of terminals in the second electrical connector, characterized in that:

at least one other trace (41) on the substrate is not ohmically connected to any of the circuit traces, the non-ohmically connected trace being arranged for coupling energy between two of said circuit traces which are in different ones of said pairs, whereby crosstalk between said two circuit traces is reduced.

2. The circuit board according to claim 1, wherein the non-ohmically connected trace is disposed on the substrate and extends closely adjacent to each of said two circuit traces for at least a portion of the respective length of each of said two circuit traces.

3. The circuit board according to claim 2, wherein the dielectric substrate has opposite major surfaces, and the non-ohmically connected trace is disposed entirely on one of the major surfaces.

4. The circuit board according to claim 2, wherein the dielectric substrate has opposite major surfaces, at least some of the circuit traces extend through

respective vias between the opposite major surfaces, and the non-ohmically connected trace at least partly surrounds one of the vias.

5. The circuit board according to claim 2, wherein the dielectric substrate has opposite major surfaces, at least some of the circuit traces have portions disposed on both of the major surfaces, and the non-ohmically connected trace extends through a via and is closely adjacent to some of the portions on both of the major surfaces.

6. The circuit board according to claim 1, wherein a plurality of said non-ohmically connected traces are disposed on the substrate closely adjacent to different ones of said circuit traces.

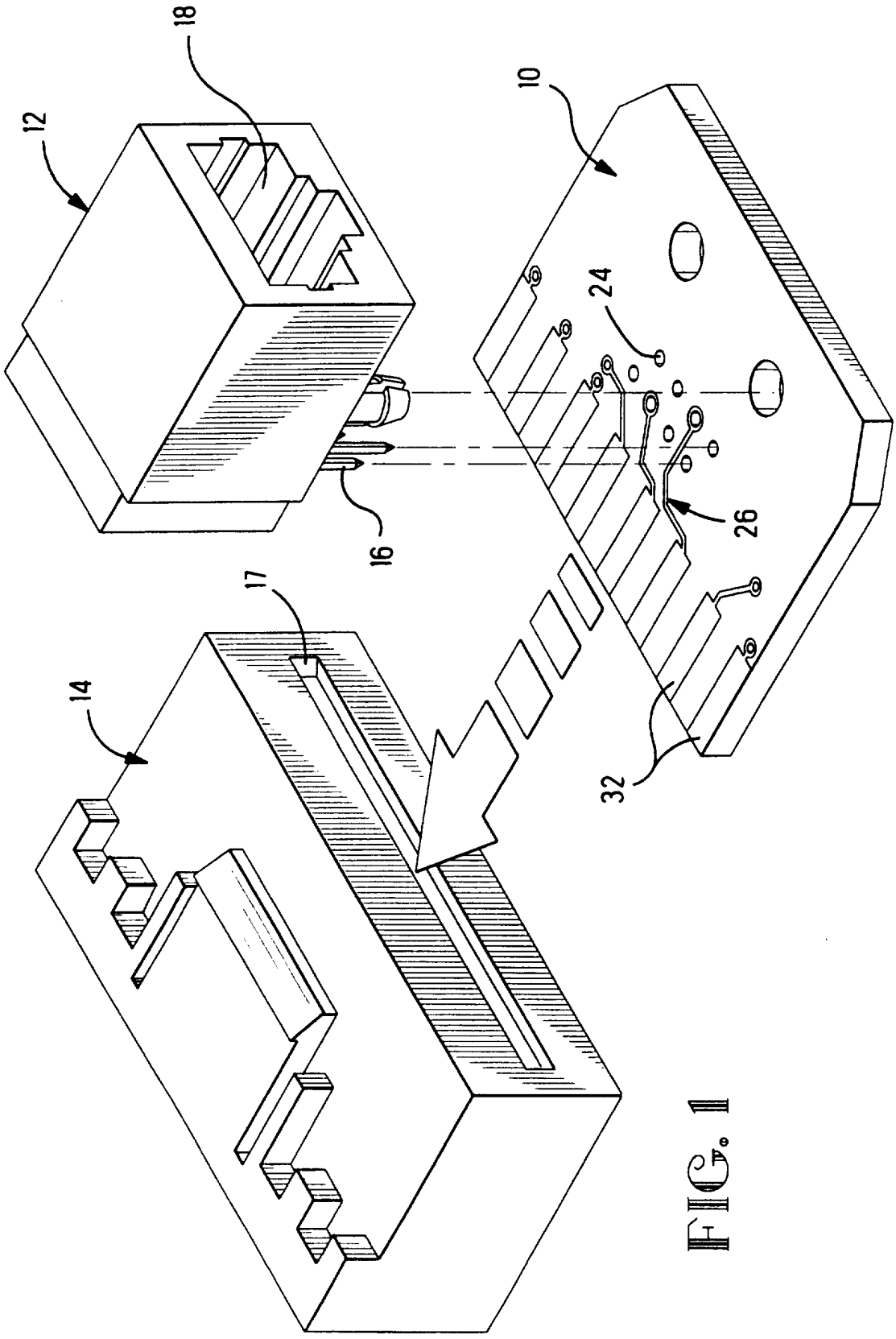

FIG. 1

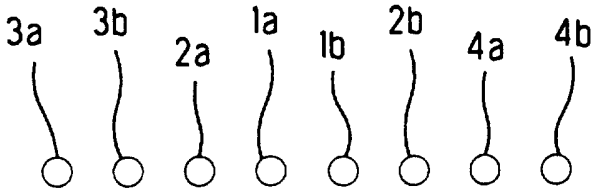

FIG. 2

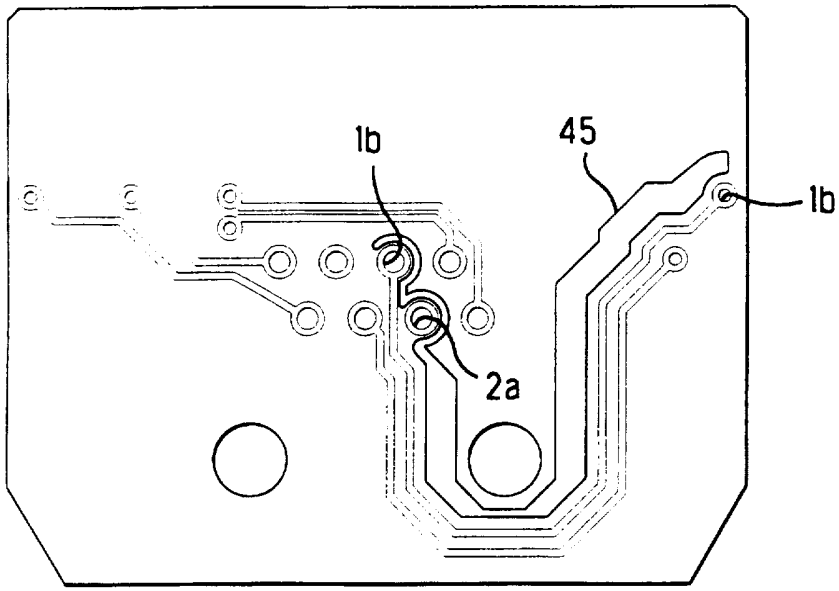

FIG. 9

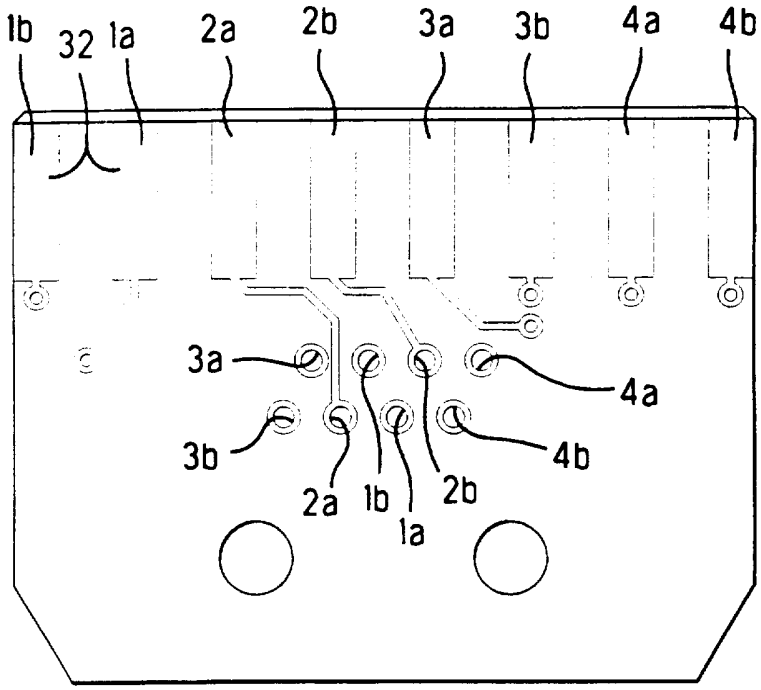
1b
32
1a
2a
2b
3a
3b
4a
4b
3a
4a
3b
4b
2a
1b
2b
1a

FIG. 3

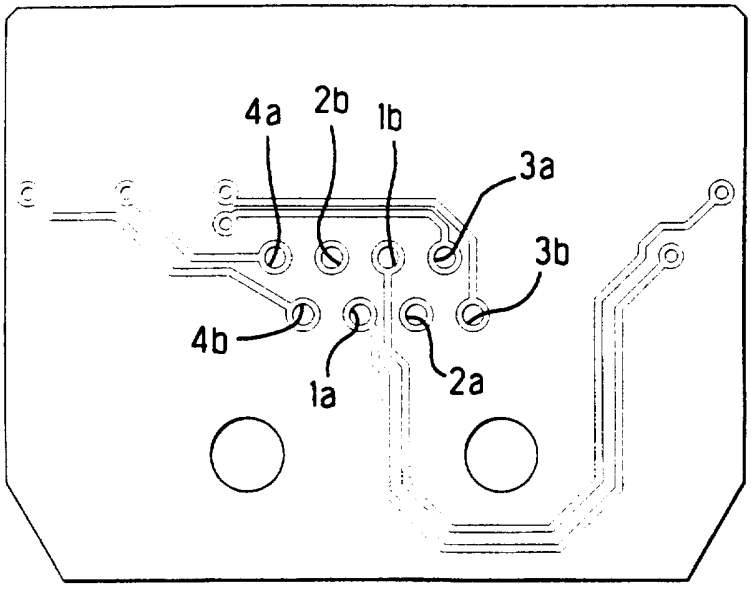
4a
2b
1b
3a
3b
4b
1a
2a

FIG. 4

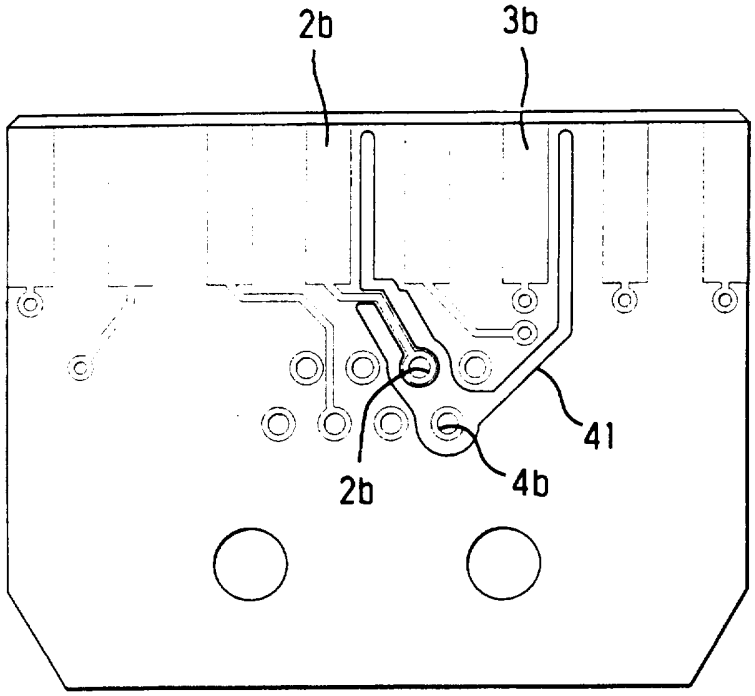

FIG. 5

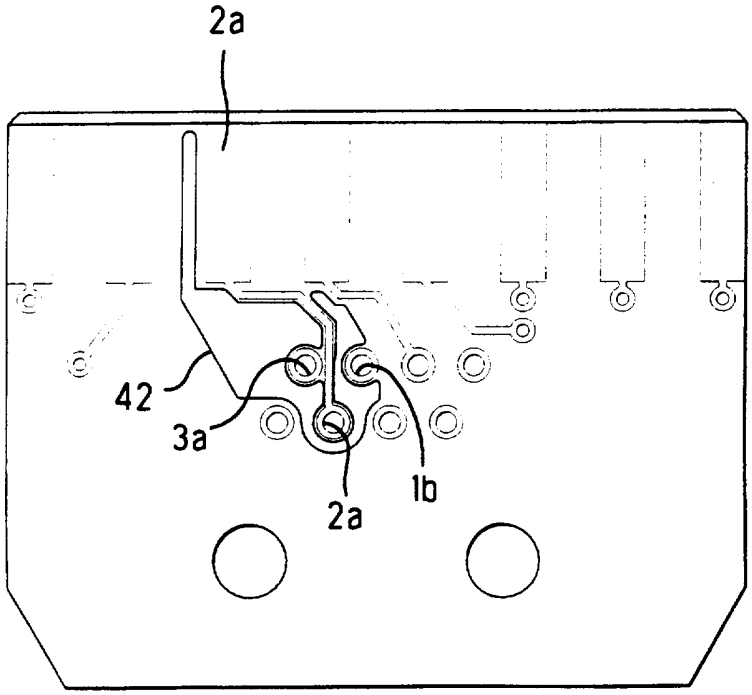

FIG. 6

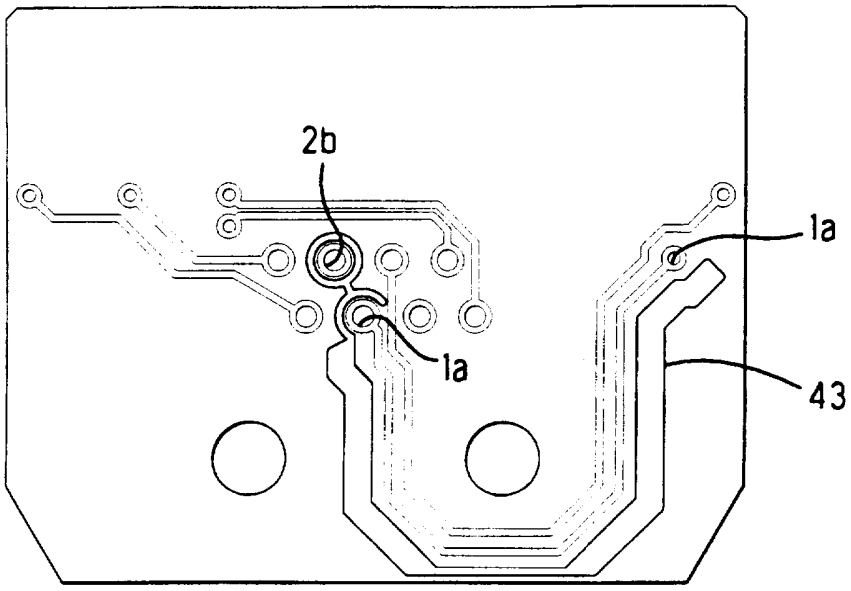

FIG. 7

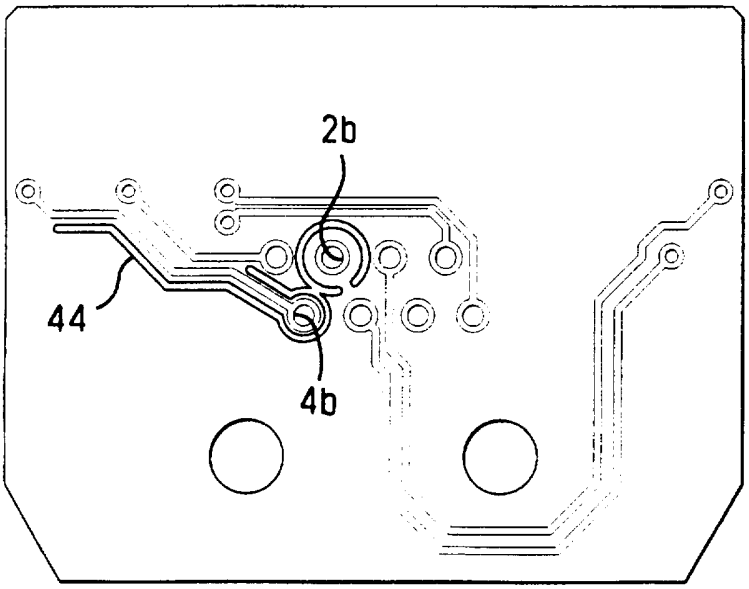

FIG. 8

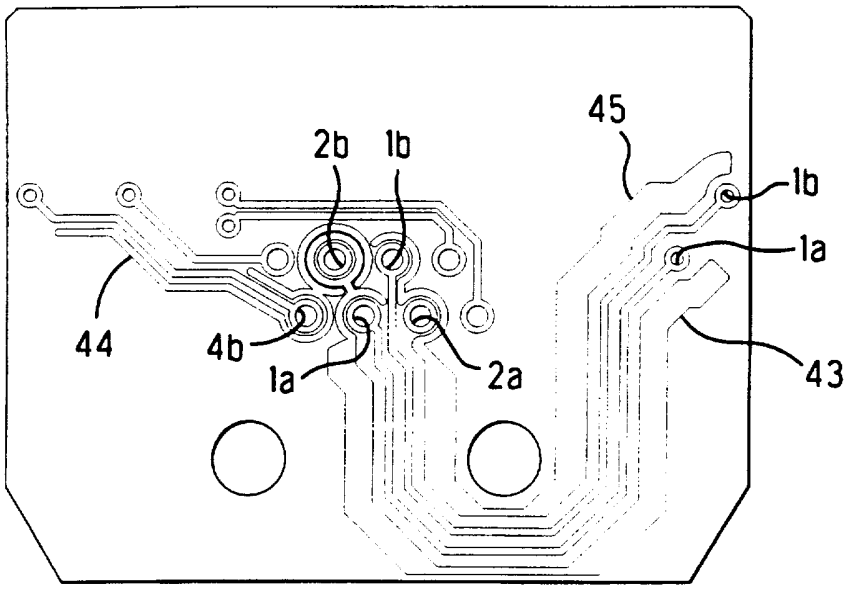

FIG. 10

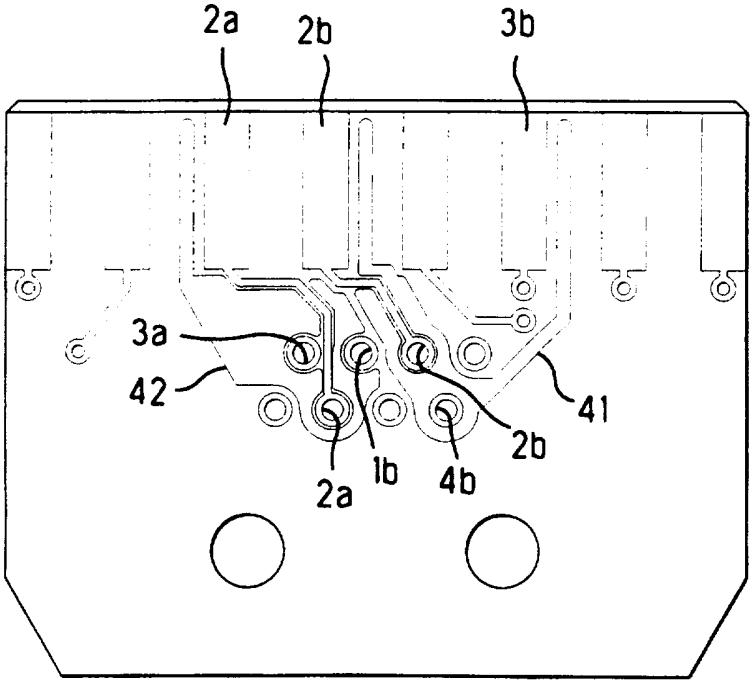

FIG. 11

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 97/02730

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H05K1/02 H01R23/00

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)
IPC 6 H05K H01R H04B

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)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 310 363 A (BROWNELL ET AL.) 10 May 1994 cited in the application see column 6, line 40 - line 54; figure 5	1
A	US 5 299 956 A (BROWNELL ET AL.) 5 April 1994 cited in the application	
A	US 5 269 708 A (DEYOUNG ET AL.) 14 December 1993	
A	GB 2 268 336 A (NORTHERN TELECOM) 5 January 1994	
A	DE 44 00 160 A (WÜRTH ELEKTRONIK GMBH) 6 July 1995	

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1

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Information on patent family members

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5310363 A	10-05-94	US 5299956 A	05-04-94
		AU 3814593 A	21-10-93
		CA 2109701 A,C	30-09-93
		WO 9319500 A	30-09-93
US 5299956 A	05-04-94	AU 3814593 A	21-10-93
		CA 2109701 A,C	30-09-93
		US 5310363 A	10-05-94
		WO 9319500 A	30-09-93
US 5269708 A	14-12-93	NONE	
GB 2268336 A	05-01-94	CA 2072380 A	26-12-93
		US 5326284 A	05-07-94
		FR 2693075 A	31-12-93
		JP 7022123 A	24-01-95
DE 4400160 A	06-07-95	NONE	