



(51) International Patent Classification:

H01R 24/00 (2006.01) **G01R 31/04** (2006.01)
G01R 27/28 (2006.01) **H01R 13/10** (2006.01)

(21) International Application Number:

PCT/US2010/020474

(22) International Filing Date:

8 January 2010 (08.01.2010)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

61/146,614 22 January 2009 (22.01.2009) US
12/613,494 5 November 2009 (05.11.2009) US

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— without international search report and to be republished upon receipt of that report (Rule 48.2(g))

[Continued on next page]

(54) Title: REDUCING FAR-END CROSSTALK IN CHIP-TO-CHIP COMMUNICATION SYSTEMS AND COMPONENTS

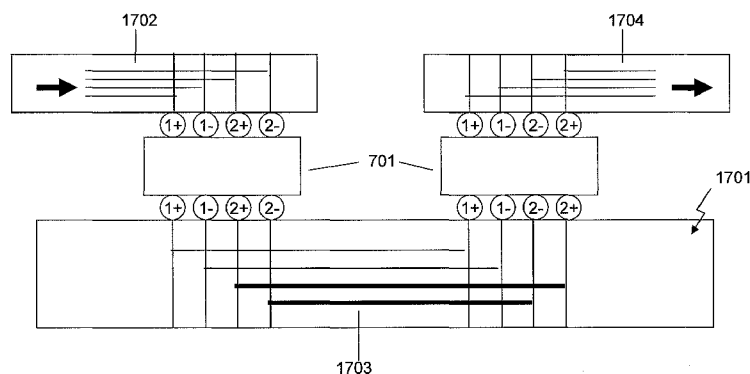


Figure 17a

(57) Abstract: The present invention involves chip-to-chip communication systems for reducing Far-End Crosstalk (FEXT) through the use of novel polarity swapping to negate the cumulative effect of FEXT. Skew adjustment is used to improve the FEXT cancellation from polarity swapping. The polarity reversal location or locations among FEXT sources are optimized to achieve maximum FEXT cancellation. The novelty polarity swapping technique can be applied to a wide variety of systems that can benefit from FEXT reduction.



— *with information submitted by the applicant concerning* — *with information submitted by the applicant concerning*
one or more priority claims (Rule 26bis.2(d)) *one or more priority claims (Rule 26bis.2(d))*

REDUCING FAR-END CROSSTALK IN CHIP-TO-CHIP COMMUNICATION SYSTEMS AND COMPONENTS

Cross-Reference to Related Application

[0001] This application is based on and claims the benefit of priority of provisional U.S. patent application No. 61/146,614, filed on January 22, 2009, and non-provisional U.S. patent application 12/613,494, filed on November 5, 2009. The foregoing applications are hereby incorporated by reference in their entirety as if fully set forth herein.

Field of the Invention

[0002] This invention relates in general to systems for reducing Far-End Crosstalk (FEXT) and, more particularly, towards the reduction of FEXT in chip-to-chip communication systems that are transmitting differential signals and may include both differential and single-ended signals.

Description of the Related Art

[0003] As the circuit speed increases, differential signaling has become a preferred method for data transmission in such applications as personal computers, servers, switches, and routers.

[0004] For the differential victim pair being considered, unwanted electromagnetic coupling (i.e., crosstalk) from neighboring aggressor pairs occurs throughout the data transmission path when at least one of these neighboring pairs is active. When the aggressor's transmitter and victim's receiver are physically far away from each other (located at different chips, for example), the crosstalk induced is called far-end crosstalk (or, FEXT). In general, the chip package, connector, cable, printed circuit board (PCB)

traces and vias are all sources of FEXT in a chip-to-chip communication system, due to the close proximity of signal lines.

[0005] Several attempts at reducing FEXT have been made through the introduction of additional self or coupling inductance and/or capacitance in either a connector or a system. The idea was based on that FEXT is proportional to the difference between inductive and capacitive coupling coefficients, so therefore by balancing these two coupling coefficients, FEXT can be reduced. US Patent 7,317,318 B2 is an example of such an attempt as applied to a connector, and US Patent 2007/0275607 A1 is an example of such an attempt as applied to a system. However, such attempts have been relatively insufficient in reducing FEXT, particularly in higher frequency systems. Therefore, there is a need for better ways to reduce FEXT.

[0006] There have also been several inventions that have implemented apparatus for reducing or cancelling crosstalk, such as US Patents 6,120,330 and 5,679,027. However, these apparatus are specifically for the reduction or cancellation of near-end crosstalk (NEXT) at frequencies of 100MHz or below in specifically RJ45 connector systems.

SUMMARY OF THE INVENTION

[0007] FEXT is a cumulative effect, and if there is more than one FEXT generator in the data transmission path (i.e., channel), the neighboring differential pair's polarity will be swapped at least once through a simple routing change. The swapping of neighboring pair's polarity results in the phase change of the following FEXT generators, so the cumulative FEXT from the following FEXT generators will cancel the cumulative FEXT from the preceding FEXT generators. Such polarity swapping, which

is independent of inductive or capacitive coupling, can be applied to a chip package, a connector, a printed circuit board (PCB), or any differential system that experiences FEXT. Low-crosstalk chip packages and connectors can be designed with polarity swapping built-in. Systems with large individual FEXT components can also see big improvements in total FEXT by applying one or more embodiments of the invention.

[0008] In one aspect of the present invention, the idea is implemented in a data transmission system that includes a transmission end, a receiving end, at least one differential pair connected to the transmission end and the receiving end, each differential pair comprising a positive signal line and a negative signal line, wherein at least one differential pair undergoes polarity reversal at one or more locations between the transmission end and the receiving end such that at least one signal transmitted to the receiving end experiences reduced FEXT due to the polarity reversal.

[0009] Additional aspects of the present invention include a system involving a transmission end; a receiving end; at least one single ended signal line; at least one differential pair connected to the transmission end and the receiving end; each differential pair comprising a positive signal line and a negative signal line; and wherein one or more differential pairs undergo polarity reversal at one or more locations between the transmission end and the receiving end.

[0010] Additional aspects of the present invention include a system that includes a transmission end, a receiving end, at least one differential pair connected to the transmission end and the receiving end, the differential pair comprising a positive signal line and a negative signal line, wherein the skew among differential pairs is minimized to improve FEXT cancellation.

[0011] Additional aspects of the present invention include a system that includes a transmission end, a receiving end, at least one single ended signal line, at least one differential pair connected to the transmission end and the receiving end, the differential pair comprising a positive signal line and a negative signal line, wherein the skew among differential pairs and single-ended signals is minimized to improve FEXT cancellation.

[0012] Additional aspects of the present invention include a system that includes a transmission end, a receiving end, at least one single ended signal line, at least one differential pair connected to the transmission end and the receiving end, the differential pair comprising a positive signal line and a negative signal line, wherein the polarity reversal location or locations among FEXT sources are optimized to achieve maximum FEXT cancellation.

[0013] Additional aspects of the present invention include a component that includes a transmission end ; a receiving end ; multiple differential pairs connected to the transmission end and the receiving end; each differential pair comprising a positive signal line and a negative signal line; wherein at least one differential pair undergoes a polarity reversal at a location between the transmission end and the receiving end.

[0014] Additional aspects of the present invention include a component that includes a transmission end; a receiving end; at least one single-ended signal; at least one differential pair connected to the transmission end and the receiving end; each differential pair comprising a positive signal line and a negative signal line; wherein at least one differential pair undergoes a polarity reversal at a location between the transmission end and the receiving end.

[0015] Additional aspects related to the invention will be set forth in part in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. Aspects of the invention may be realized and attained by means of the elements and combinations of various elements and aspects particularly pointed out in the following detailed description and the appended claims.

[0016] It is to be understood that both the foregoing and the following descriptions are exemplary and explanatory only and are not intended to limit the claimed invention or application thereof in any manner whatsoever.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The accompanying drawings, which are incorporated in and constitute a part of this specification exemplify the embodiments of the present invention and, together with the description, serve to explain and illustrate principles of the inventive technique. Specifically:

[0018] Figure 1 shows an example chip-to-chip communication system where FEXT can occur.

[0019] Figure 2 shows an example connector where FEXT can occur.

[0020] Figure 3 illustrates two differential pairs of a system that contains two sources of FEXT.

[0021] Figure 4 illustrates an embodiment of the present invention implementing polarity swapping when applied to the differential system of Figure 3.

[0022] Figure 5 illustrates an embodiment of the present invention implementing polarity swapping and skew minimization applied to the differential system of Figure 3.

[0023] Figure 6 illustrates the FEXT of the differential pairs of Figures 3-5.

- [0024]** Figure 7 illustrates typical mezzanine connectors.
- [0025]** Figure 8 illustrates the pin assignment for the three piece BGA mezzanine connector of Figure 7a at both the entrance and exit.
- [0026]** Figure 9 illustrates the FEXT between differential pairs 8 and 9 on a typical mezzanine connector of Figure 7a and Figure 8.
- [0027]** Figure 10 illustrates an example embodiment of the invention as applied to a mezzanine connector.
- [0028]** Figures 11a and 11b illustrate the pin assignment of the mezzanine connector at the entrance and exit respectively, as indicated by an embodiment of the invention.
- [0029]** Figure 12 illustrates the improvement on the FEXT between differential pairs 8 and 9 on the mezzanine connector of Figures 10, 11a and 11b.
- [0030]** Figure 13 illustrates typical backplane connectors.
- [0031]** Figure 14 illustrates example embodiments of the invention as applied to backplane connectors.
- [0032]** Figure 15a illustrates a conventional card edge connector, and Figure 15b is an example embodiment of the invention as applied to a card edge connector.
- [0033]** Figures 16a and 16b illustrates a section of data transmission path in a chip-to-chip communication system with two connectors.
- [0034]** Figures 17a and 17b illustrate the application of an embodiment of the present invention to the system design of Figure 16.
- [0035]** Figure 18 compares the FEXT of a typical system design versus the system design applying an embodiment of the invention.

[0036] Figure 19 illustrates how the FEXT between the single-ended signal 1- and differential pair signal 2+ and 2- is also significantly reduced with the application of an embodiment of the present invention.

[0037] Figures 20a-d show examples utilizing one or more embodiments of the present invention with one or more polarity reversals among a plurality of FEXT sources.

DETAILED DESCRIPTION

[0038] In the following detailed description, reference will be made to the accompanying drawing(s), in which identical functional elements are designated with like numerals. The aforementioned accompanying drawings show by way of illustration, and not by way of limitation, specific embodiments and implementations consistent with principles of the present invention. These implementations are described in sufficient detail to enable those skilled in the art to practice the invention and it is to be understood that other implementations may be utilized and that structural changes and/or substitutions of various elements may be made without departing from the scope and spirit of present invention. The following detailed description is, therefore, not to be construed in a limited sense.

[0039] Figure 1 shows an example of a chip-to-chip communication system, where the signal sent by the transmitter 101 can go through multiple chip packages 102, connectors 103, and traces 104 and vias 105 in printed circuit boards (PCB) 106 before arriving at the receiver 107. Chip packages, connectors, PCBs, and cables are all components that can be utilized within such a chip-to-chip system.

[0040] Figure 2 shows an example of an electrical connector, where a signal being transmitted through the connector can go through mating portions 201, retention portions 202, solder tails 203, conductors 204 or vias 205 before or after the connector.

[0041] Figure 3 illustrates two differential pairs 300-301 with two FEXT sources 302-303. These FEXT sources can be chip packages, connectors, PCB vias or PCB traces as shown in Figure 1. These FEXT sources can also be mating portions, retention portions, solder tails within a connector, traces, or vias before or after a connector as shown in Figure 2. These FEXT sources can also be bond wires, traces, lead frames, or solder balls within a chip package. To illustrate how the polarity swapping idea works, we consider an example of two differential pairs, in which there are two FEXT sources, and the traces before, between, and after the sources contribute no crosstalk.

[0042] Figure 4 shows the modified differential pairs with the inventive polarity swapping technique, where the relative positions of two differential pairs change from (1+, 1-, 2+, 2-) to (1+, 1-, 2-, 2+) at some point 401 between the two FEXT sources. Pair 2 has 5ps more delay than pair 1 in this case because pair 2 requires additional trace length to swap positions. In this example, by swapping the relative positions of the positive and negative signal lines of the aggressor differential pair, a large amount of the accumulated FEXT becomes negated by the subsequent inverted FEXT.

[0043] Figure 5 illustrates the modified differential pairs with the inventive polarity swapping technique 401 and a skew adjustment technique 501 at some point between the two FEXT sources. In this example, by swapping the relative positions of the positive and negative signal lines of the aggressor differential pair and matching the

delay between the two differential pairs, the accumulated FEXT becomes almost completely negated by the subsequent inverted FEXT.

[0044] Figure 6 gives the FEXT of the differential pairs in Figures 3-5 in frequency domain. From this plot, it can be seen that FEXT is significantly reduced by this polarity swapping technique. The reason for such reduction can be roughly explained by the following. The two sources of coupling between Pairs 1 and 2 are temporarily assumed to be of equal magnitude for simplicity. The polarity swapping results in these two FEXTs being opposite in phase, and therefore they cancel each other. When there is a 5ps skew introduced by the additional length required to swap the relative positions of the aggressor pair, the two FEXTs arriving at the receiver are not exactly opposite in phase, resulting in more FEXT than when the skew is eliminated. By adding some delay to the victim pair as done in Figure 5 to remove the skew, the FEXT cancellation can be significantly improved as seen in Figure 6. Rigorous mathematical derivation can be used to identify the propagating modes and explain the small left-over FEXT after the polarity change and skew elimination. Of especial interest in this simulation is the significant reduction of FEXT in high frequency systems where the differential pair is transmitting a signal of greater than 1 GHz. By utilizing the novel polarity reversal swapping technique, such higher frequency systems can be designed without significant worry in regards to FEXT. This would enable circuit speeds to go much faster than the current technology allows. However, lower frequency systems will also benefit from the use of the novel polarity swapping technique, which can be especially useful in systems that utilize both a differential pair and a single ended signal line.

[0045] This optimal location for the polarity swap is where the FEXT accumulated from one side is close to 50% of the total FEXT. Although, some FEXT will still be cancelled even if the FEXT induced before the swap is unequal to the FEXT after the swap.

[0046] In some cases, it may be optimal to swap multiple times among a plurality of FEXT sources.

[0047] Moreover, the inventive polarity swapping technique can also be applied to the design of individual components. Figure 7 shows examples of a two piece mezzanine connector 705 in Figure 7b and a three piece mezzanine connector 701 in Figure 7a that the polarity swapping technique can be applied to. The two piece connector is comprised of a plug 706 and a receptacle 707. The three piece connector is comprised of two receptacles 702 and one interposer 703. The interposer, in turn, contains multiple wafers 704, where each wafer has 10 signal traces and one ground plane. Solder balls are attached to the connector; their corresponding pin assignments for three wafers are shown in Figure 8; and differential FEXT between Pairs 8 and 9 is shown in Figure 9. Figure 10 shows the improved three piece connector implementing this polarity swapping technique. The side view 1001 shows multiple wafers inserted into the interposer. The signal traces swap their relative positions on the wafers for every other differential pair. Two types of wafers are used. One type has the center pair swapped 1005. The other type has the center pair non-swapped 1006. These two wafer types are placed adjacent to each other within the interposer so that the swapped pairs are staggered from one wafer to the next. In this configuration the FEXT from the nearest neighbors are drastically reduced. Details of the swapping portion 1003 can be

seen from the perspective view 1002. To achieve optimal FEXT cancellation, the wafers were designed to have very little inter-pair skew. This was done by purposely adding delay to the non-swapped pairs. Details of the delay adjustment portion can be seen in 1004. The corresponding pin assignments of solder balls and differential FEXT between Pairs (8+, 8-) and (9+, 9-) are shown in Figures 11a-b and 12, respectively. It is apparent that utilizing one or more embodiments of the invention results in FEXT of Figure 12 being significantly less than FEXT of Figure 9. This polarity swapping technique is also applicable to the two piece mezzanine connector.

[0048] The polarity swapping technique can also be applied to backplane connectors. Figure 13 shows examples of a three piece backplane connector 1301 and a two piece backplane connector 1305. The three piece backplane connector consists of two receptacles 1302-1303 and an interposer 1304. The two piece backplane connector is comprised of a plug 1306 and a receptacle 1307. Examples of how the two piece backplane connector 1401 and the three piece backplane connector 1402 can utilize the polarity swapping technique are illustrated in Figure 14.

[0049] Figure 15 illustrates an example of how this polarity swapping technique can be applied to a card edge connector. A conventional card edge connector 1501 has differential pairs that go straight through. Details of the straight pairs 1503 are shown. A card edge connector utilizing this polarity swapping technique 1502 has differential pairs that swap. Details of this implementation 1504 show how these pairs are swapped.

[0050] Figure 16a shows a portion of a conventional chip-to-chip communication system where two connectors 701 from Figure 7 are used in a "channel" with 3" PCB

trace 1602, 6" PCB trace 1603, and 3" PCB trace 1604 routed on the inner signal layers as an example. The top view layout of the PCB 1601 linking the two connectors is shown in Figure 16b. Details of how the PCB traces are routed out from the connectors are shown in the detail views 1605-1606. In this conventional way of routing, the polarities of the two differential pairs, (1+, 1-) and (2+, 2-), are maintained from one connector to the next. The relative locations of the positive and negative signal lines remain the same at each connector. With such conventional routing, the FEXT generated by each connector will accumulate.

[0051] Figure 17a shows a portion of a chip-to-chip communication system utilizing one or more embodiments of the present invention. Similar to Figure 16a, it consists of two connectors 701 in a "channel" with 3" PCB trace 1702, 6" PCB trace 1703, and 3" PCB trace 1704 routed on the inner signal layers. The top view layout of the PCB 1701 linking the two connectors is shown in Figure 17b. Details of how the PCB traces are routed out from the connectors are shown in detail views 1705-1706. It can be seen that, unlike the system of Figure 16a-b, the system of Figure 17a-b has the polarity of differential pair (2+, 2-) swapped from one connector to the next. The differential pairs are configured 1+, 1-, 2+, and 2- at the connector to the left and configured 1+, 1-, 2-, and 2+ at the connector to the right. The relative locations of differential pair (2+, 2-) have changed from one connector to the next. Because of the polarity swapping, the FEXT generated from the two connectors will cancel.

[0052] Figure 18 shows the FEXT between differential pairs (1+, 1-) and (2+, 2-) for the systems of Figures 16a-b and Figures 17a-b. It can be seen that utilizing one or more embodiments of the invention reduces FEXT dramatically in a system.

[0053] So far, we have focused on FEXT between two differential pairs. However, the embodiments of the invention are applicable to FEXT between a differential pair and a single-ended signal as well. Let us consider 1+ and 1- in Figures 16 and 17 as two independent single-ended signals. Figure 19 shows that FEXT between single-ended 1- and differential pair (2+, 2-) is also significantly reduced with the utilization of one or more embodiments of the invention. From this example, it is therefore possible to reduce FEXT even in a system involving a differential pair and a neighboring single-ended signal.

[0054] The embodiments of the invention are not limited to only one polarity swap between two FEXT sources. The polarity can be swapped more than once among a plurality of FEXT sources. Figures 20a-d show such examples, each consisting of four FEXT sources and at least one polarity reversal. Figure 20a shows a victim differential pair going through four FEXT sources. An aggressor differential pair, which does not swap polarity, is located along side the victim pair but is not shown here. At the first FEXT source 2001, 10% of the aggressor signal couples over to the victim pair. At the second FEXT source 2002, 20% couples over. Since the polarity is maintained from the first source to the second, the FEXT accumulates to 30%. The victim pair then swaps polarity before entering the third FEXT source 2003, where 30% of the aggressor signal couples over. Because the polarity of the victim pair was swapped before entering the third source, the FEXT from 2003 is opposite in polarity to the FEXT accumulated from 2001-2002, and they cancel each other out. This leaves 0% FEXT accumulated after three FEXT sources. The fourth FEXT source 2004 contributes 40% FEXT, so the total FEXT accumulated at the end of the system is 40%. This is a significant improvement

over a system or components of the system which would have seen 100% FEXT if routed in the conventional fashion.

[0055] The FEXT in this example can be further reduced to 20% by swapping polarity at different locations as in Figures 20b-c. Figure 20b shows an example where the polarity is swapped three times: once after 2001, once after 2002, and once after 2003. In this example 40% FEXT of one polarity, accumulated from 2001 and 2003, cancels the 60% FEXT of opposite polarity, accumulated from 2002 and 2004, leaving 20% FEXT in the victim pair. Figure 20c has the victim pair swap once between 2003 and 2004. 40% FEXT from 2004 is canceled by 60% FEXT from 2001-2003, resulting in 20% FEXT left over.

[0056] With some optimization, it can be seen that FEXT can be cancelled even further using one or more embodiments of the present invention. Figure 20d shows an example where polarity is swapped between 2001 and 2002 and between 2003 and 2004. 50% FEXT of one polarity is coupled from sources 2001 and 2004, and 50% FEXT of the opposite polarity is couple from sources 2002 and 2003. These FEXT sources cancel each other out and leave a minimal amount of FEXT in the victim pair. To achieve maximum FEXT cancellation, the location or locations of where to swap polarity can be optimized. The examples of Figures 20a-d have shown four different examples of how this polarity swapping invention can be used to dramatically reduce FEXT.

[0057] Moreover, other implementations of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be considered as

exemplary only, with a true scope and spirit of the invention being indicated by the following claims.

WHAT IS CLAIMED IS:

1. A chip-to-chip communication system reducing Far End Crosstalk (FEXT), comprising:
a transmission end;
a receiving end;
multiple differential pairs connected to the transmission end and the receiving end; each differential pair comprising a positive signal line and a negative signal line; and wherein at least one of the differential pairs undergoes polarity reversal at one or more locations between a plurality of FEXT sources.
2. The chip-to-chip communication system of claim 1, wherein the positive signal line and the negative signal line of each of the multiple differential pairs are disposed at relative physical locations to each other, and wherein polarity reversal is achieved by exchanging the relative physical locations of the positive signal line and the negative signal line of each differential pair undergoing the polarity reversal at the one or more locations between the plurality of FEXT sources.
3. The chip-to-chip communication system of claim 1, wherein each of the multiple differential pairs further comprise an assignment corresponding to the positive signal line and the negative signal line, the assignment being disposed at the transmission end and the receiving end, and wherein polarity reversal is achieved by routing the at least one differential pair undergoing polarity reversal from the transmission end to the receiving end such that the assignment of the positive signal

line and the negative signal line at the receiving end differs from the assignment of the positive signal line and the negative signal line at the transmission end.

4. The chip-to-chip communication system of claim 1, wherein the differential pairs are at least partially disposed in at least one of a printed circuit board, an electrical connector, a chip package, or a cable.

5. The chip-to-chip communication system of claim 1, wherein every other differential pair undergoes polarity reversal.

6. The chip-to-chip communication system of claim 5, wherein the multiple differential pairs are arranged in a staggered array configuration.

7. The chip-to-chip communication system of claim 1, wherein delay of at least one differential pair is adjusted such that skew is reduced.

8. The chip-to-chip communication system of claim 1, wherein the one or more polarity reversal locations among FEXT sources comprise at least one predetermined point optimized to achieve maximum FEXT cancellation.

9. A chip-to-chip communication system reducing Far End Crosstalk (FEXT), comprising:
a transmission end;

a receiving end;
at least one single ended signal line;
at least one differential pair connected to the transmission end and the receiving end; each differential pair comprising a positive signal line and a negative signal line; and wherein at least one differential pair undergoes polarity reversal at one or more locations between a plurality of FEXT sources.

10. The chip-to-chip communication system of claim 8, wherein the positive signal line and the negative signal line of each of the at least one differential pairs are disposed at relative physical locations to each other, and wherein polarity reversal is achieved by exchanging the relative physical locations of the positive signal line and the negative signal line of each differential pair undergoing polarity reversal at the one or more locations between the plurality of FEXT sources.

11. The chip-to-chip communication system of claim 9, wherein each of the multiple differential pairs further comprise an assignment disposed at the transmission end and at the receiving end, the assignment corresponding to the positive signal line and the negative signal line; and wherein polarity reversal is achieved by routing the at least one differential pair undergoing polarity reversal from the transmission end to the receiving end such that the assignment of the positive signal line and the negative signal line at the receiving end differs from the assignment of the positive signal line and the negative signal line at the transmission end.

12. The chip-to-chip communication system of claim 9, wherein the at least one differential pair or the at least one single ended signal line are at least partially disposed in at least one of a printed circuit board, an electrical connector, a chip package, or a cable.

13. The chip-to-chip communication system of claim 8, wherein delay is adjusted in one of the at least one of differential pair or in the at least one single-ended signal line such that skew is reduced.

14. The chip-to-chip communication system of claim 9, wherein the one or more polarity reversal locations among FEXT sources comprise at least one predetermined point optimized to achieve maximum FEXT cancellation.

15. A component reducing Far End Crosstalk (FEXT), comprising:
a transmission end;
a receiving end;
multiple differential pairs connected to the transmission end and the receiving end; each differential pair comprising a positive signal line and a negative signal line; and wherein at least one of the differential pairs undergoes polarity reversal at one or more locations between a plurality of FEXT sources.

16. The component of claim 15, wherein the component is one of a printed circuit board, an electrical connector, a chip package, or a cable.

17. The component of claim 15, wherein the positive signal line and the negative signal line of each of the multiple differential pairs are disposed at relative physical locations to each other, and wherein polarity reversal is achieved by exchanging the relative physical locations of the positive signal line and the negative signal line of each differential pair undergoing polarity reversal at the one or more locations between the plurality of FEXT sources.

18. The component of claim 15, wherein each of the multiple differential pairs further comprise an assignment disposed at the transmission end and at the receiving end, the assignment corresponding to the positive signal line and the negative signal line; and wherein polarity reversal is achieved by routing the at least one differential pair undergoing polarity reversal from the transmission end to the receiving end such that the assignment of the positive signal line and the negative signal line at the receiving end differs from the assignment of the positive signal line and the negative signal line at the transmission end.

19. The component of claim 15, wherein every other differential pair undergoes polarity reversal.

20. The component of claim 19, wherein the multiple differential pairs are arranged in a staggered array configuration.

21. The component of claim 15, wherein delay is adjusted in at least one differential pair such that skew is reduced.

22. The component of claim 15, wherein the one or more polarity reversal locations among FEXT sources comprise at least one predetermined point optimized to achieve maximum FEXT cancellation.

23. A component reducing Far End Crosstalk (FEXT), comprising:
a transmission end;
a receiving end;
at least one single ended signal line;
at least one differential pair connected to the transmission end and the receiving end; each differential pair comprising a positive signal line and a negative signal line; and wherein at least one differential pair undergoes polarity reversal at one or more locations between a plurality of FEXT sources.

24. The component of claim 23, wherein the positive signal line and the negative signal line of each of the at least one differential pair are disposed at relative physical locations to each other, and wherein polarity reversal is achieved by exchanging the relative physical locations of the positive signal line and the negative signal line of each differential pair undergoing the polarity reversal at the one or more locations between the plurality of FEXT sources.

25. The component of claim 23, wherein each of the multiple differential pairs further comprise an assignment disposed at the transmission end and at the receiving end, the assignment corresponding to the positive signal line and the negative signal line; and wherein polarity reversal is achieved by routing the at least one differential pair undergoing polarity reversal from the transmission end to the receiving end such that the assignment of the positive signal line and the negative signal line at the receiving end differs from the assignment of the positive signal line and the negative signal line at the transmission end.

26. The component of claim 23, wherein the component is one of a printed circuit board, an electrical connector, a chip package, or a cable.

27. The component of claim 23, wherein delay is adjusted in one of the at least one of differential pair or in the at least one single-ended signal line such that skew is reduced.

28. The component of claim 23, wherein the one or more polarity reversal locations among FEXT sources comprise at least one predetermined point optimized to achieve maximum FEXT cancellation.

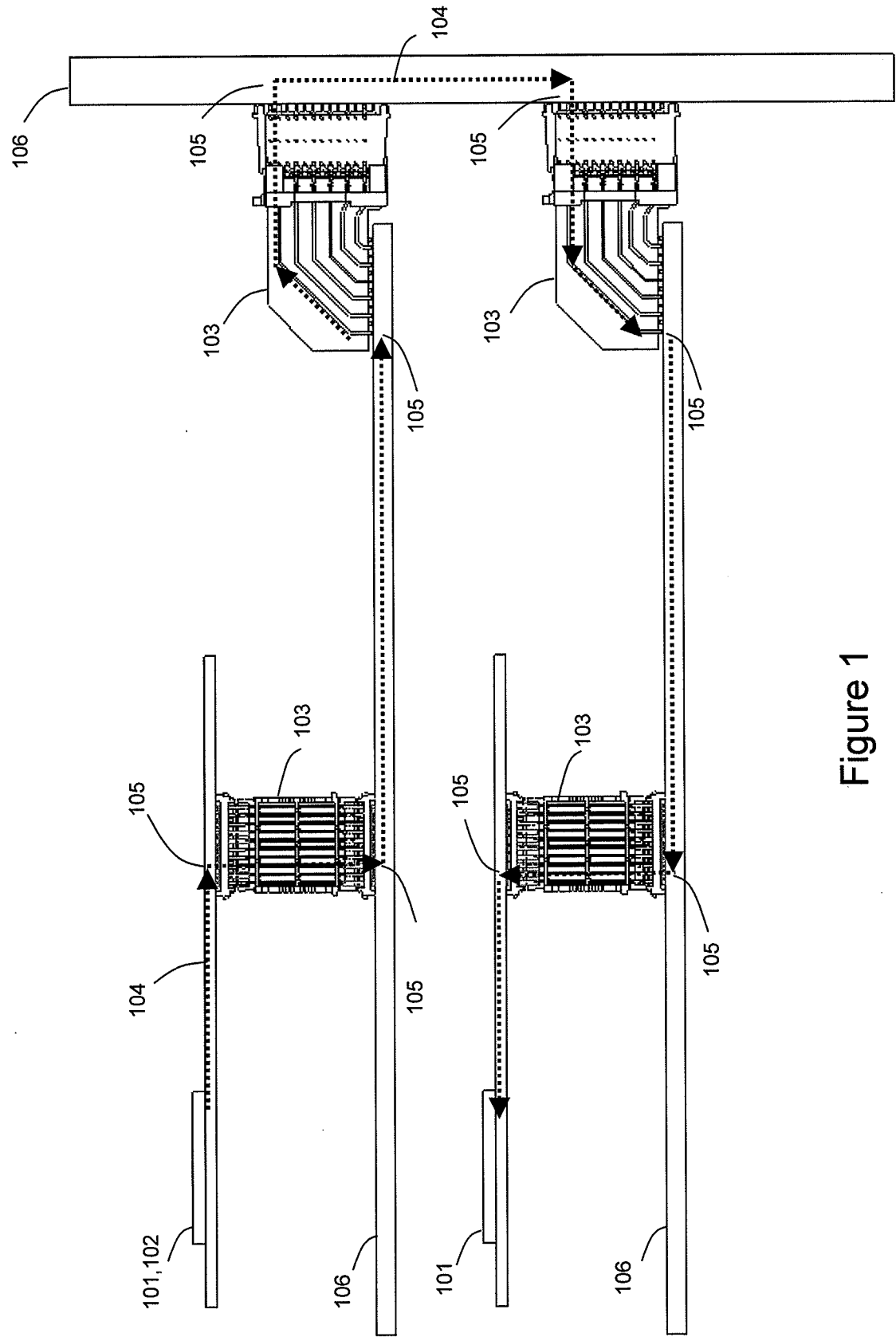


Figure 1

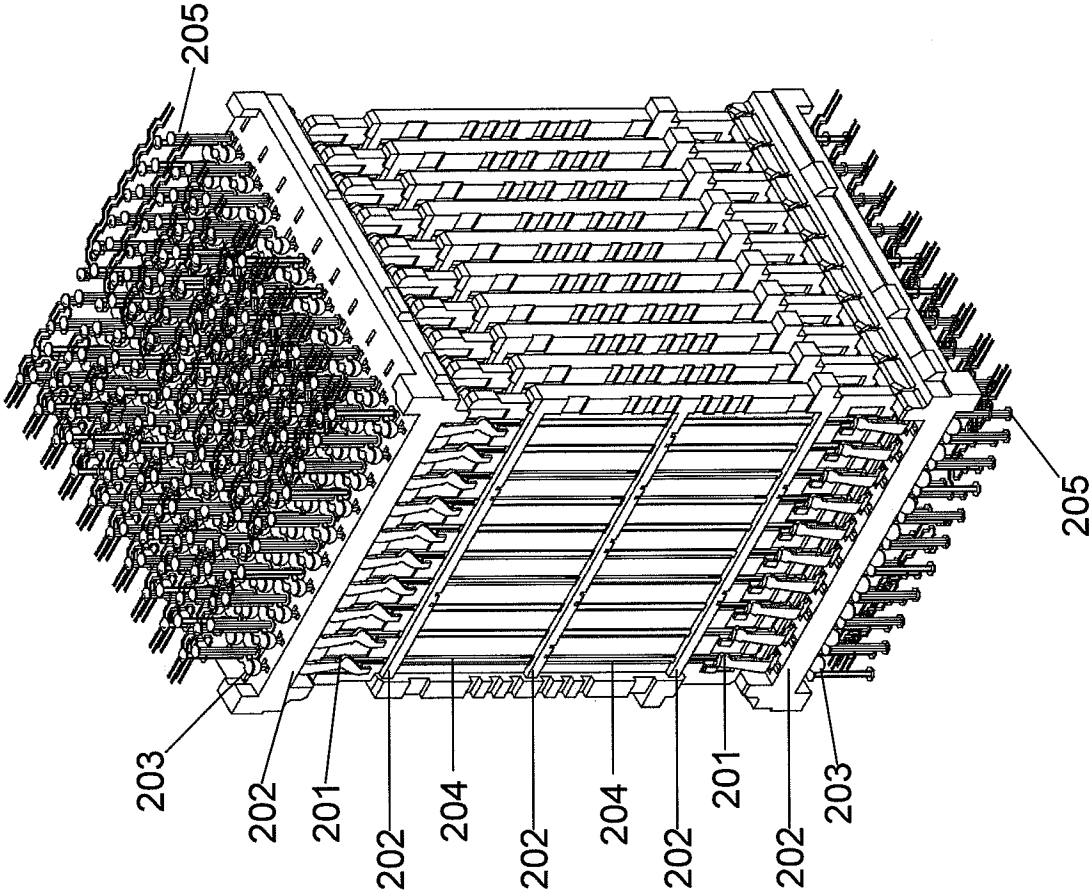


Figure 2

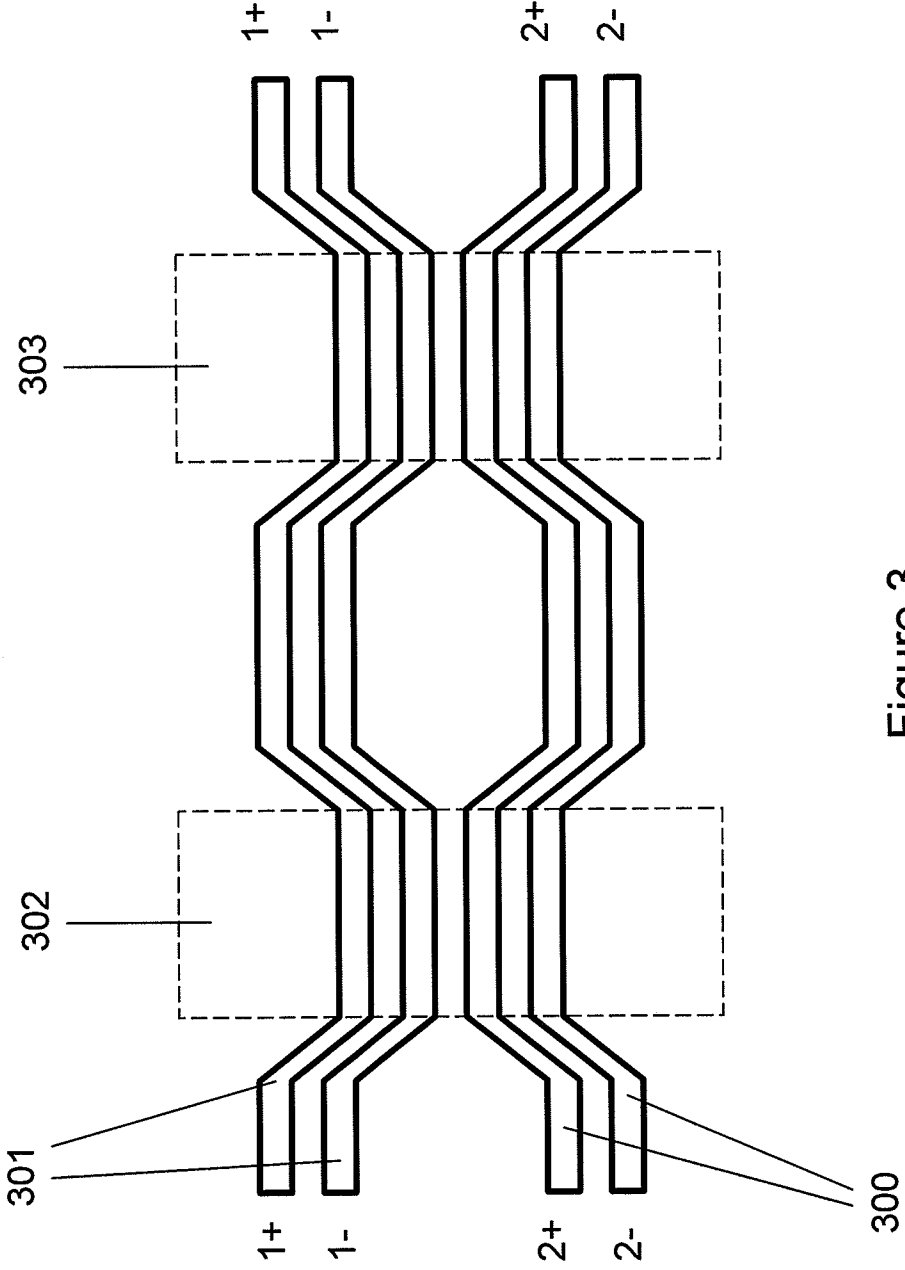


Figure 3

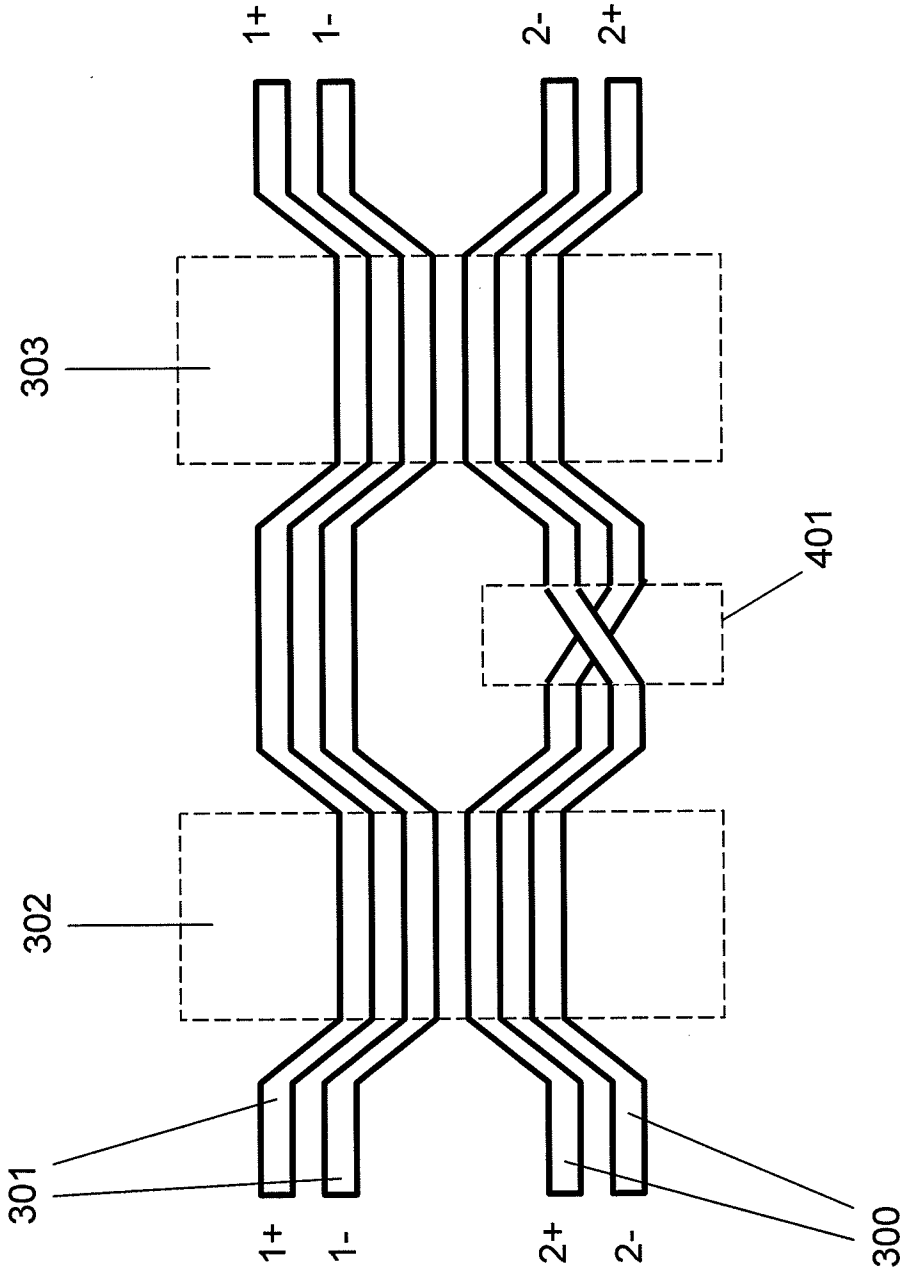


Figure 4

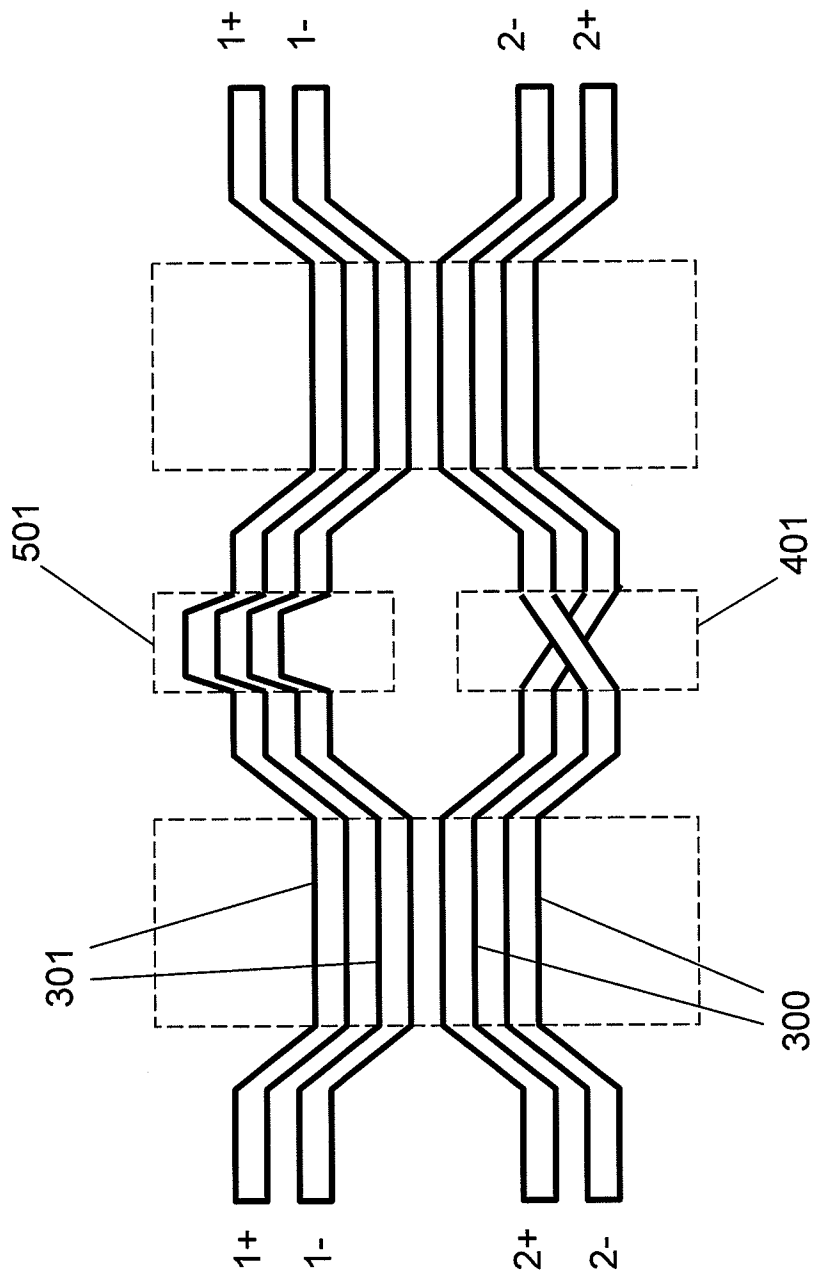


Figure 5

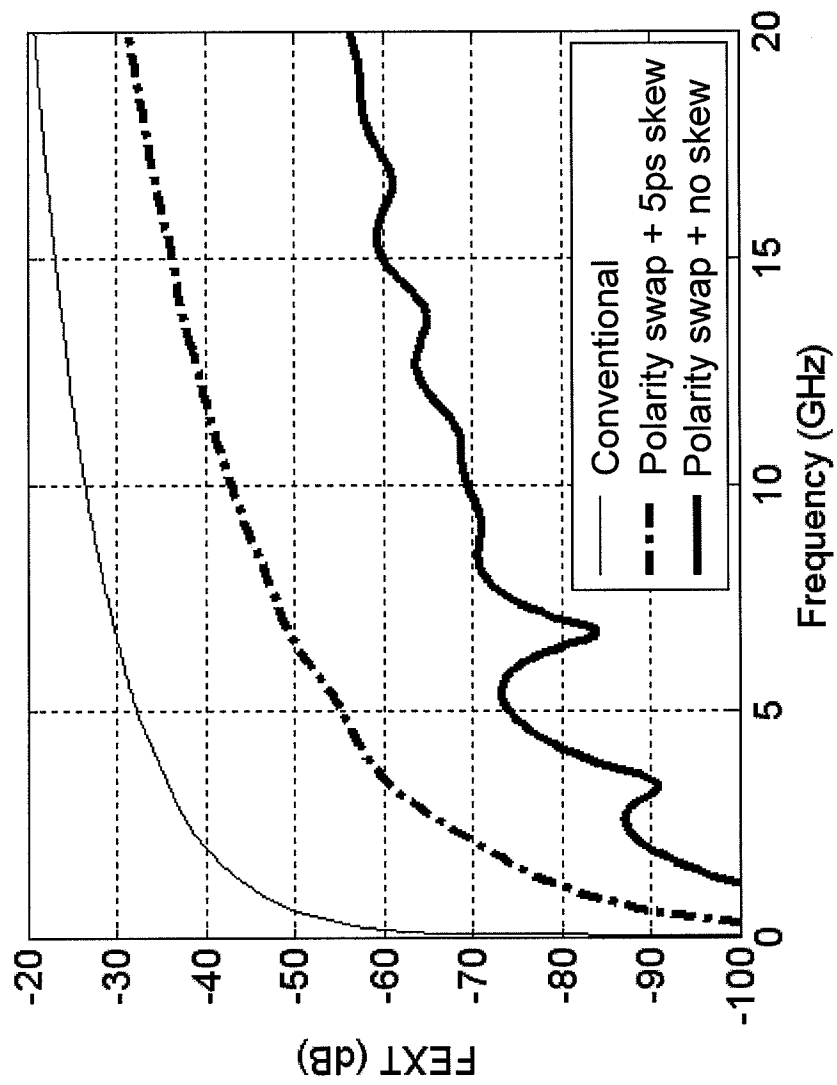


Figure 6

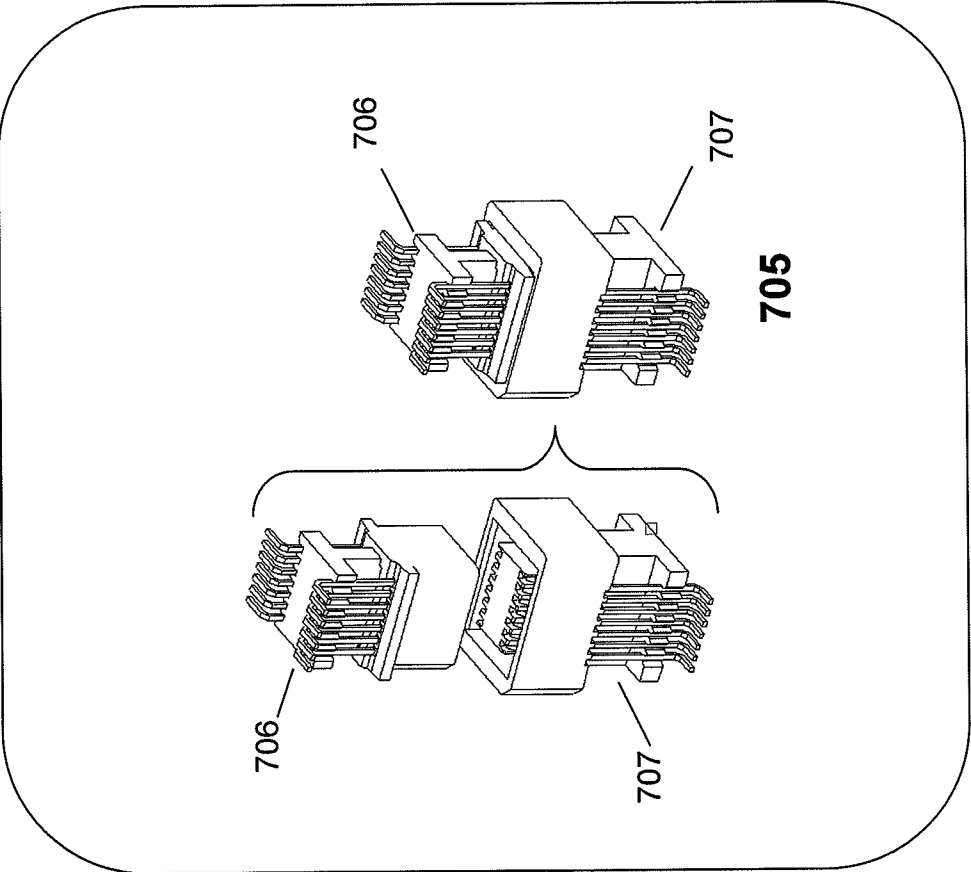


Figure 7a

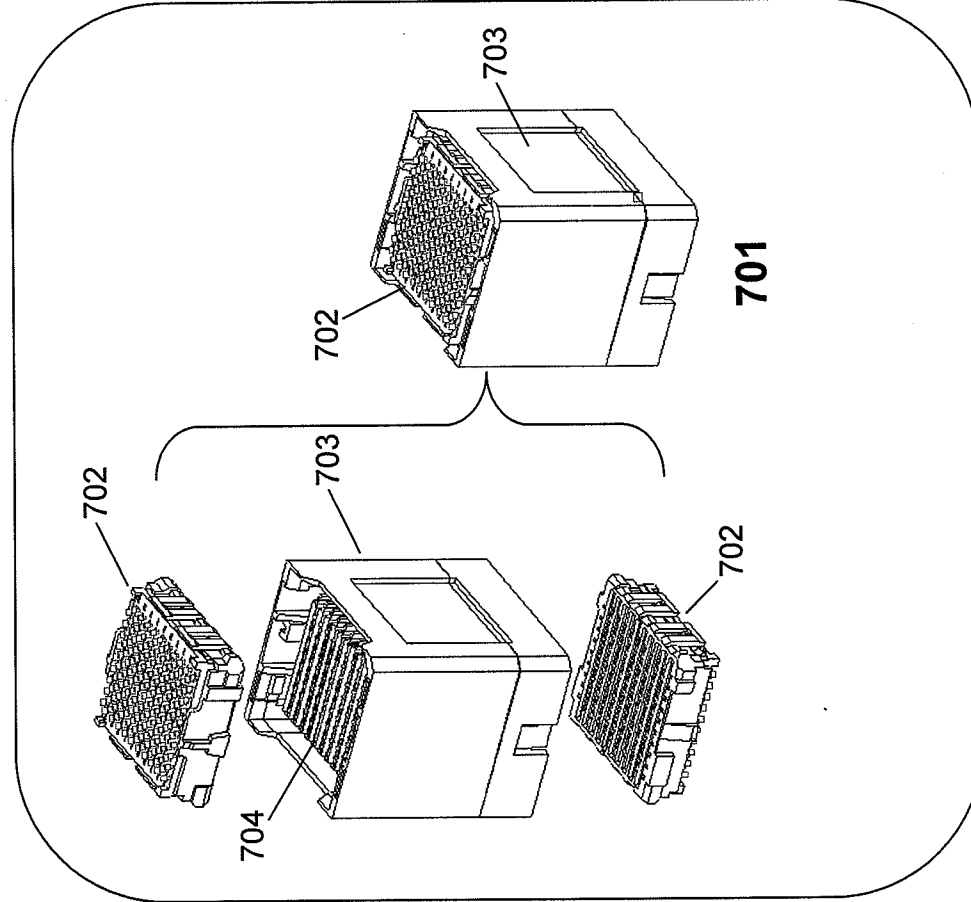


Figure 7b

Figure 7

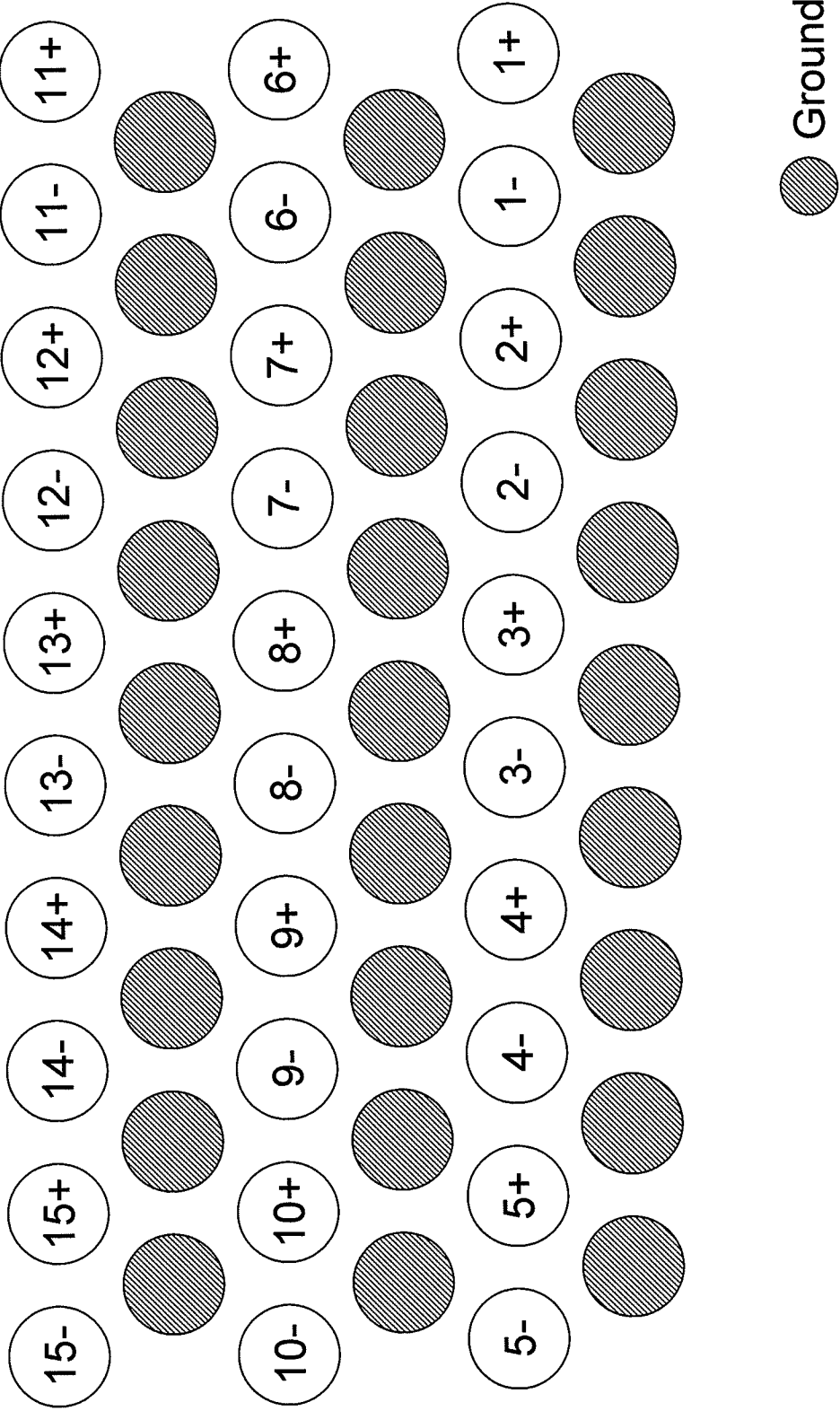


Figure 8

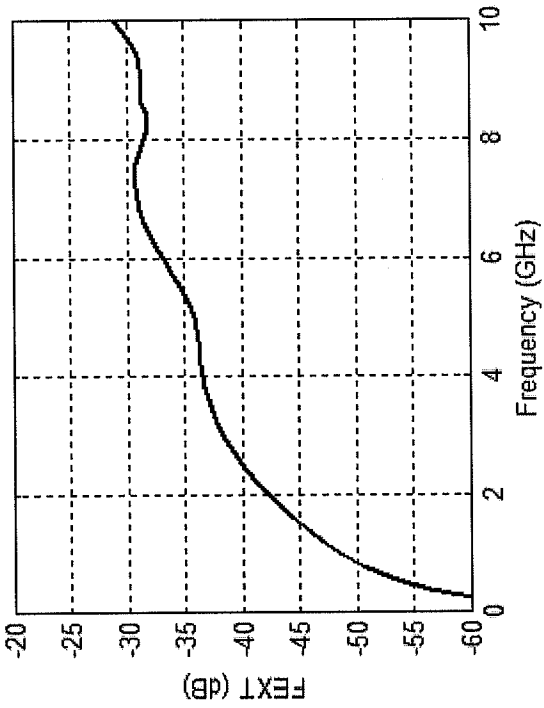


Figure 9

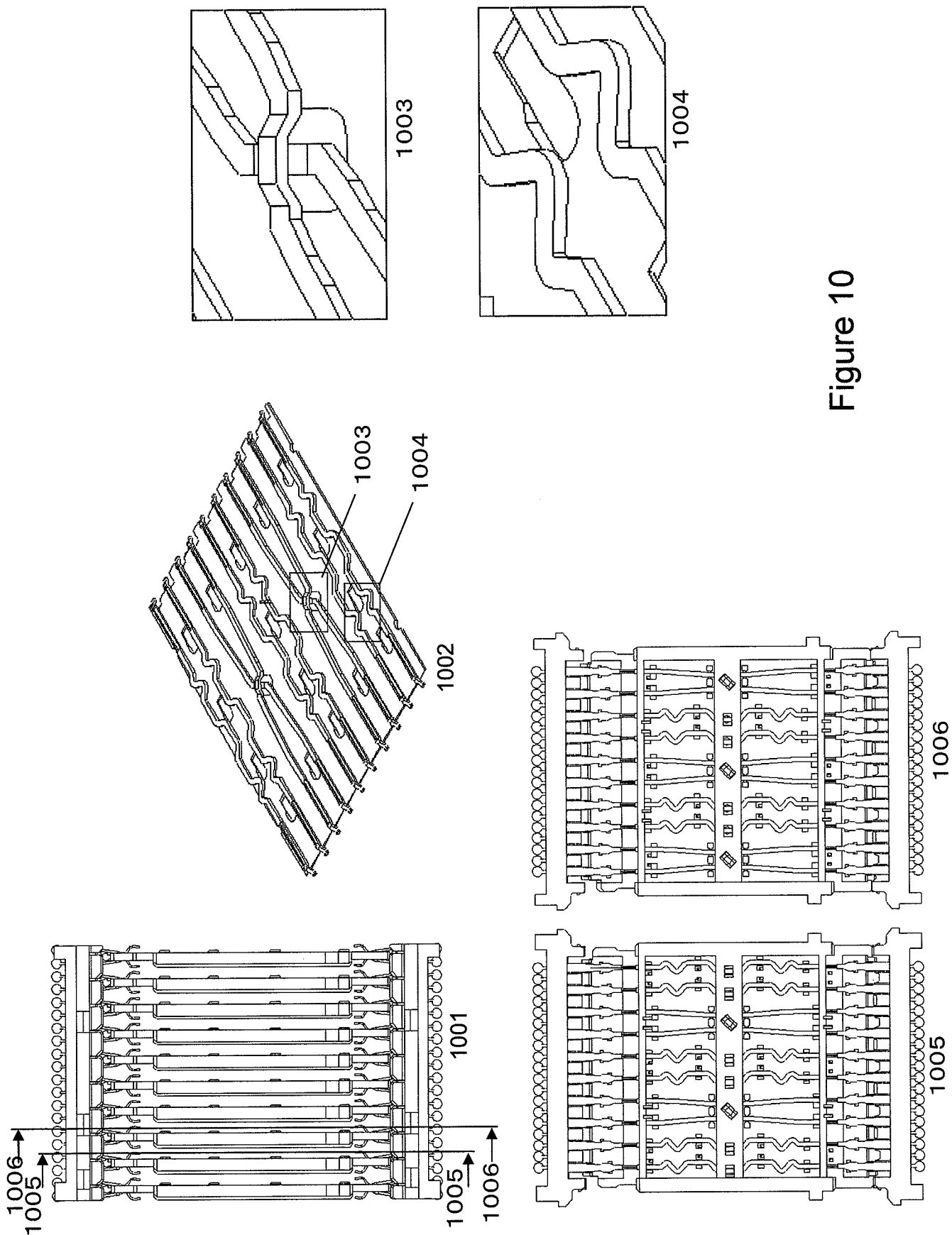


Figure 10

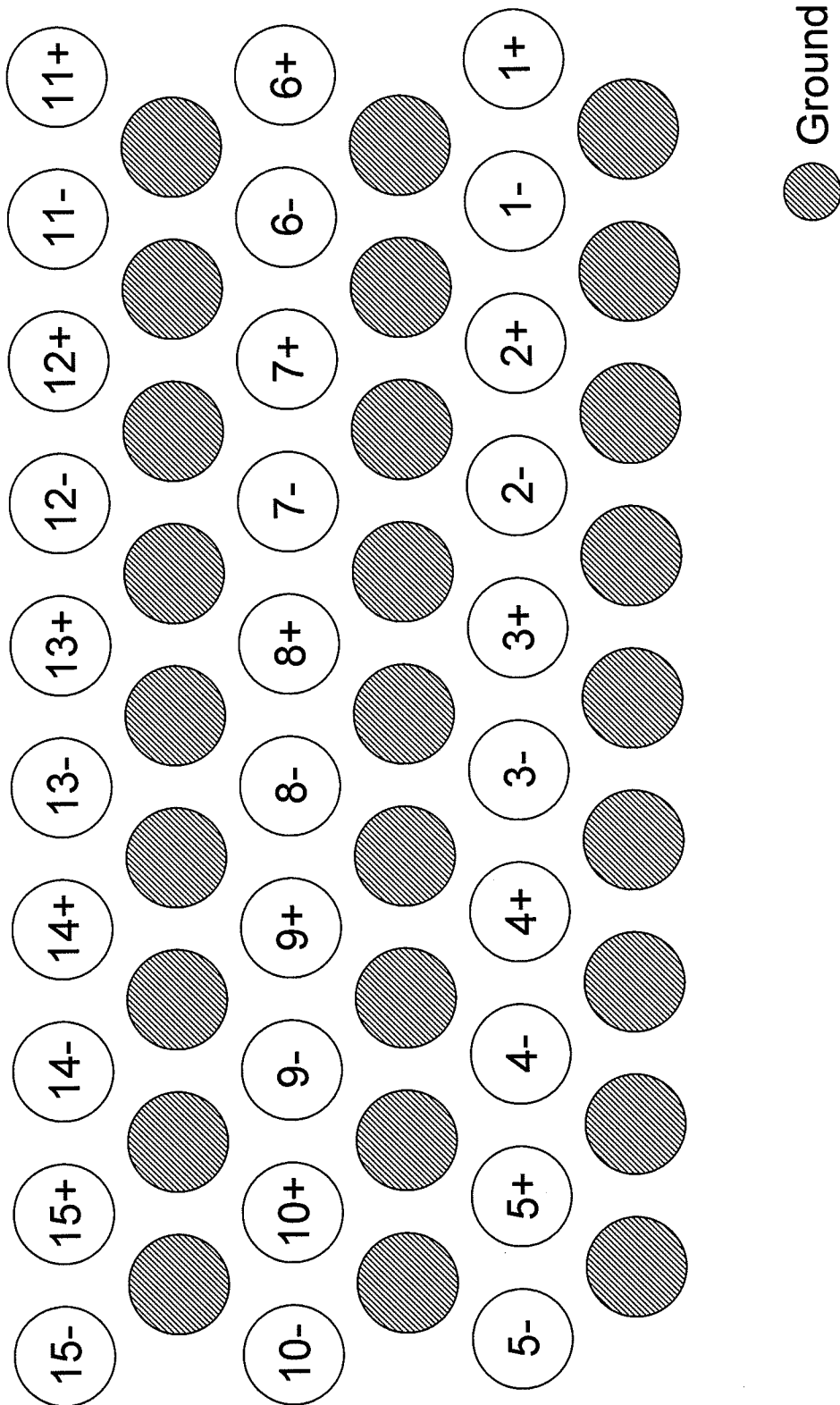


Figure 11(a)

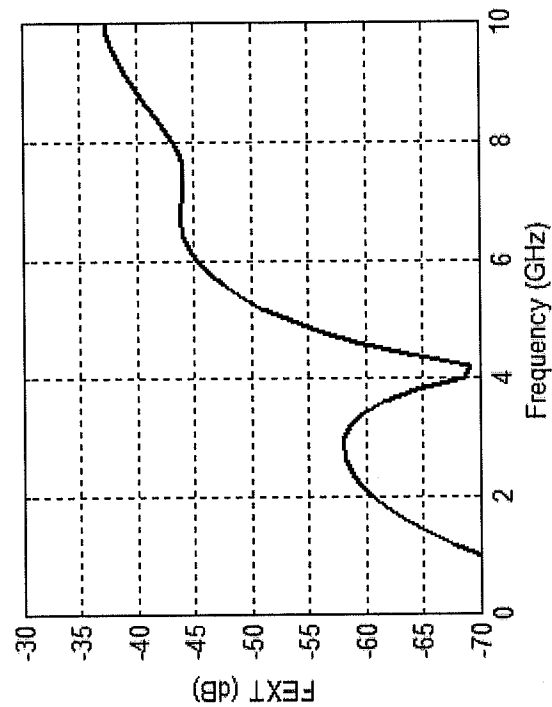


Figure 12

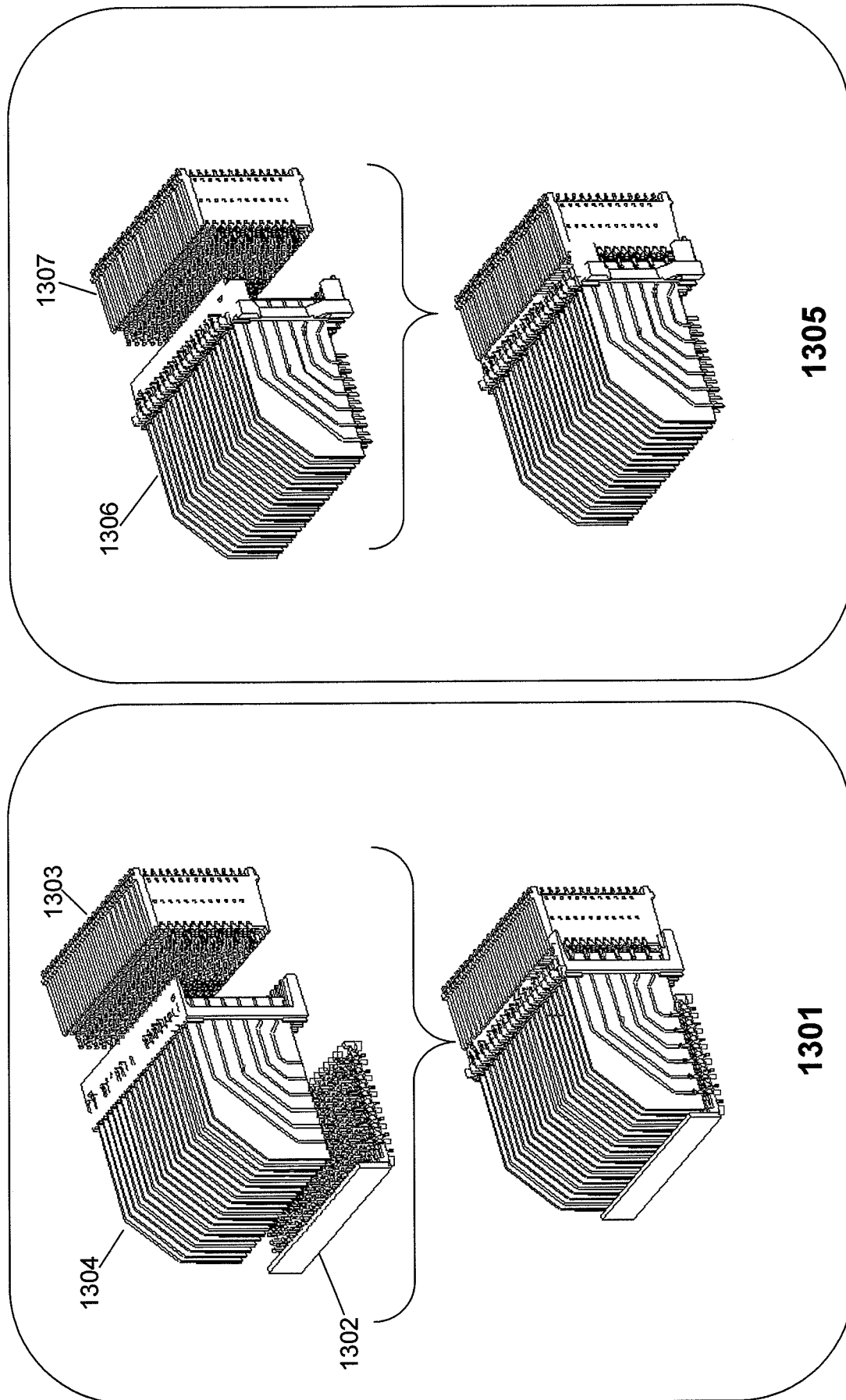


Figure 13

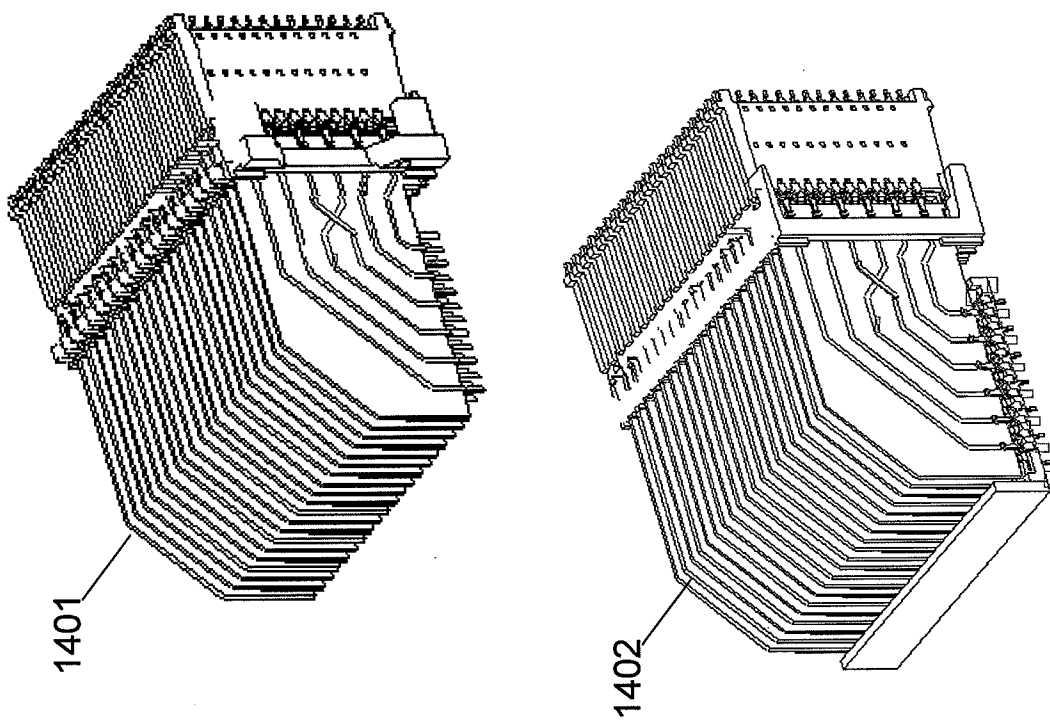


Figure 14

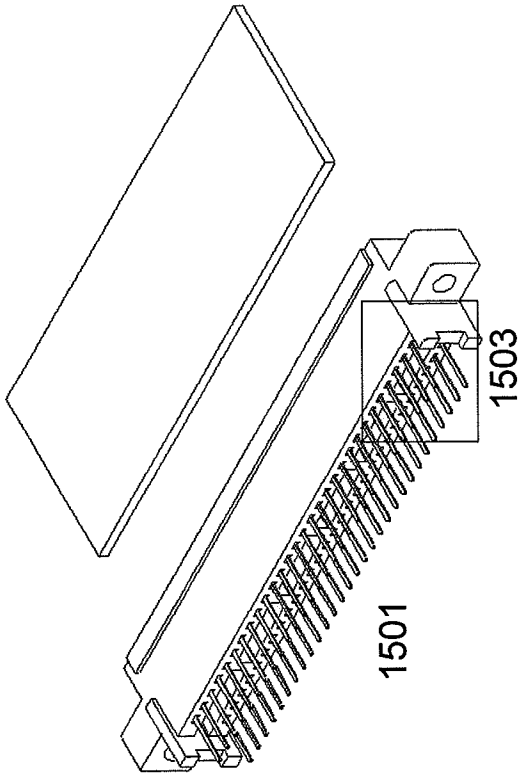


Figure 15a

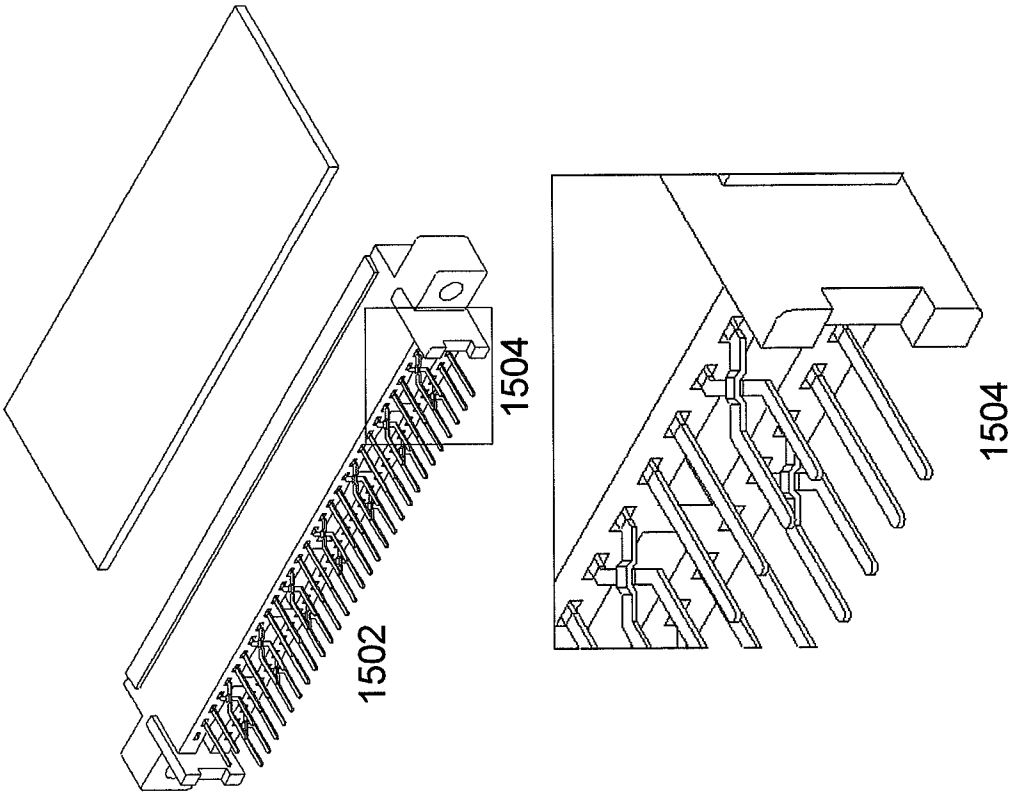


Figure 15b

Figure 15

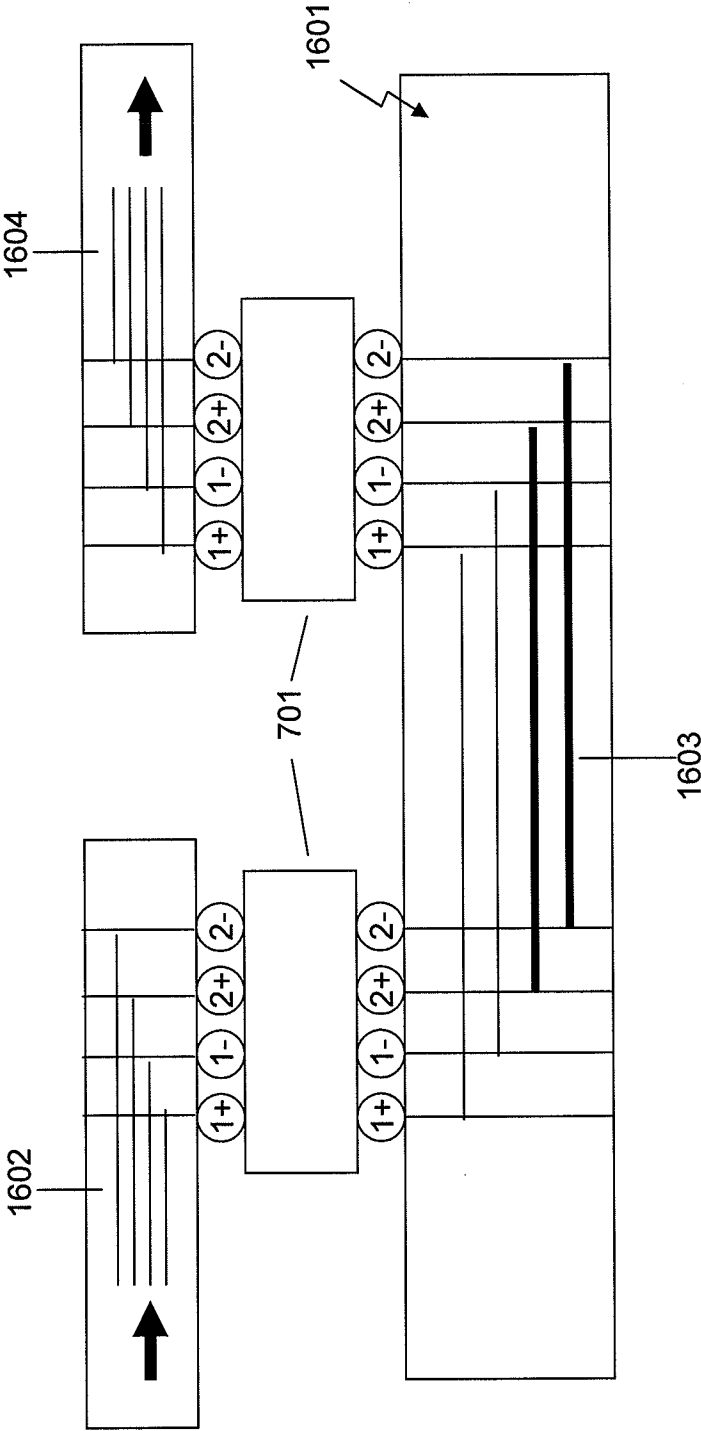


Figure 16a

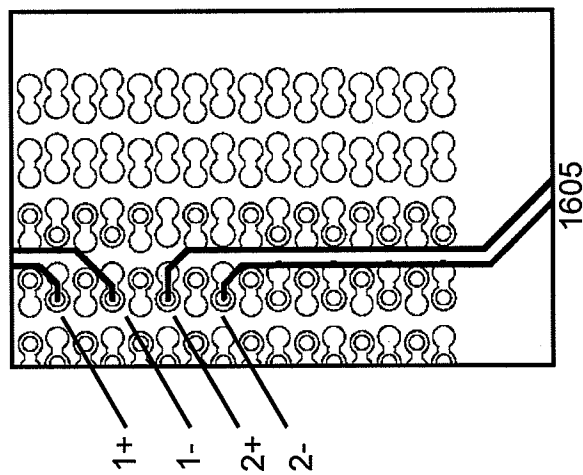
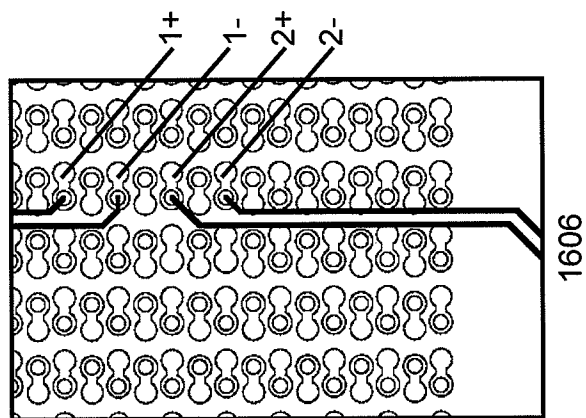
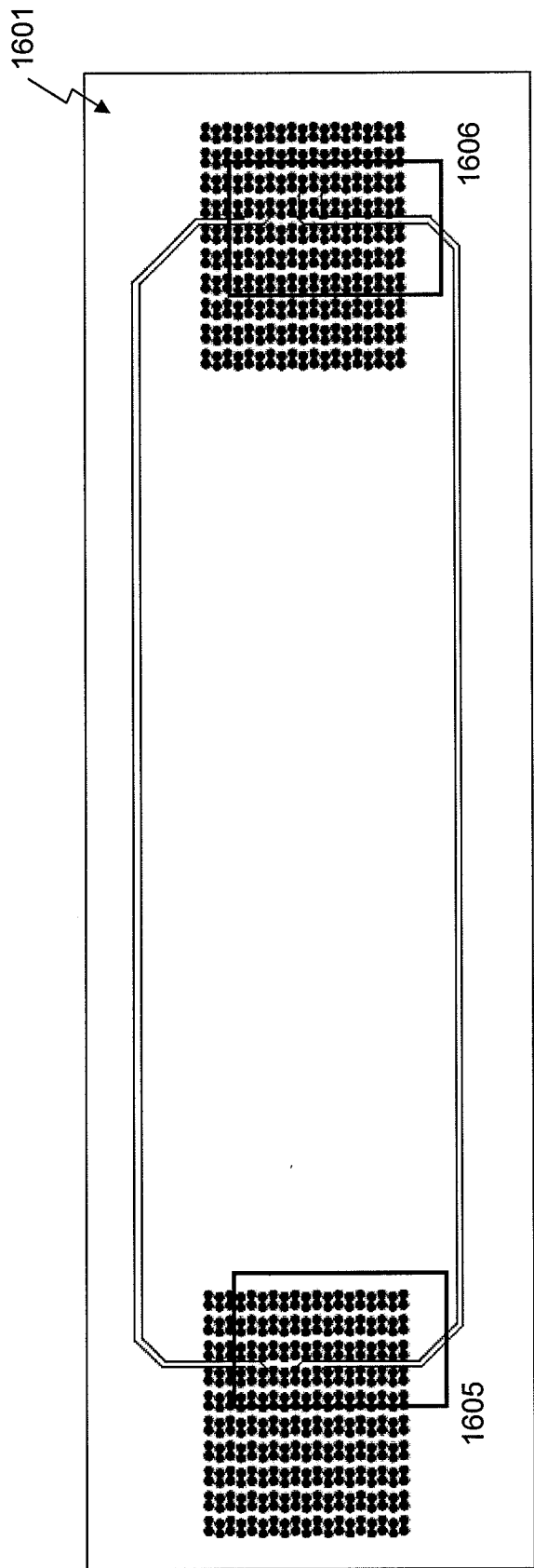


Figure 16b

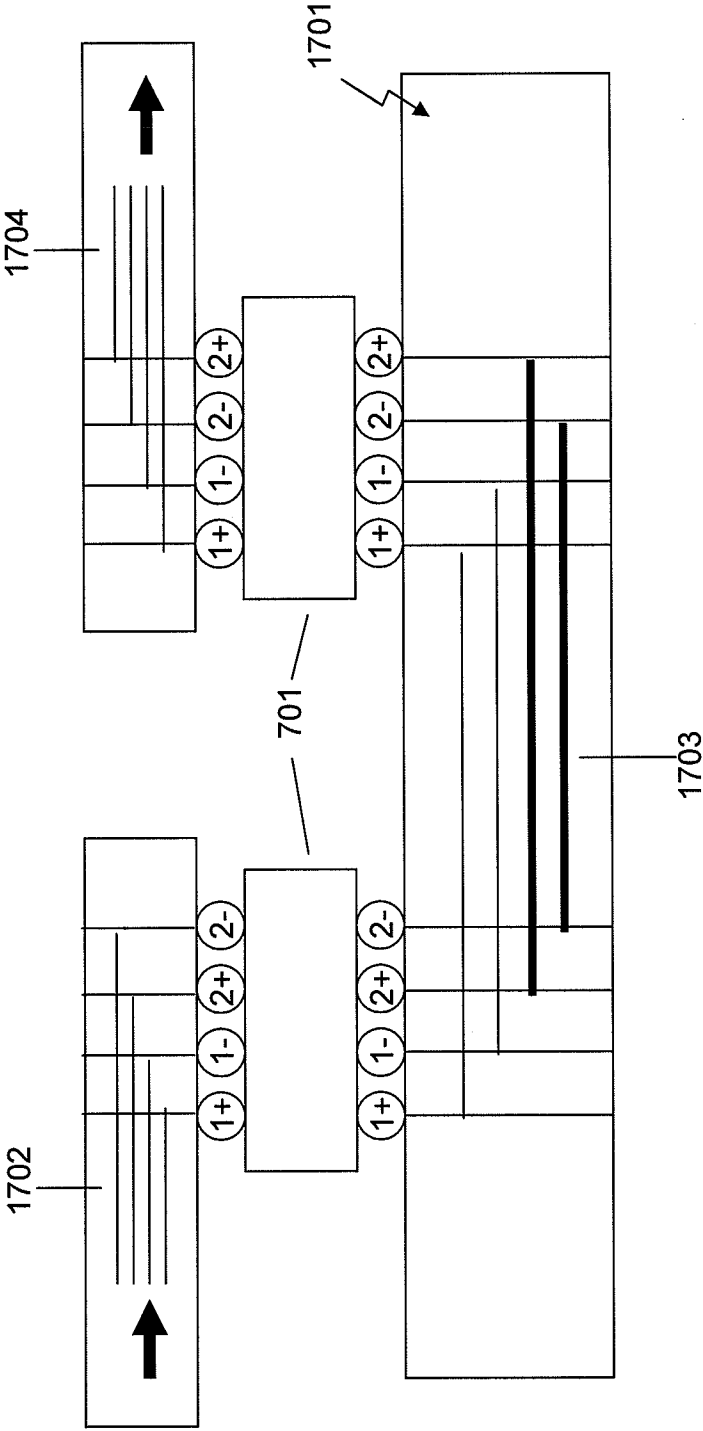


Figure 17a

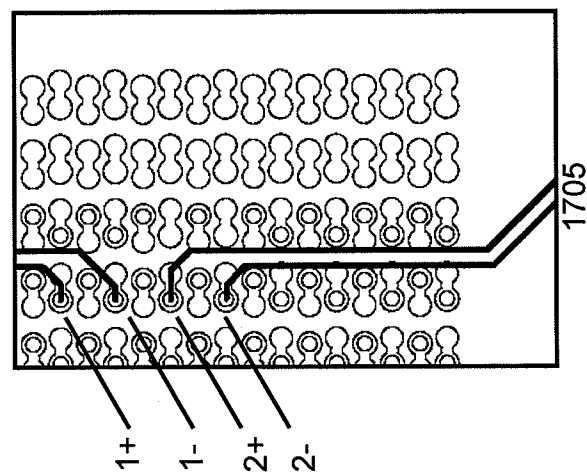
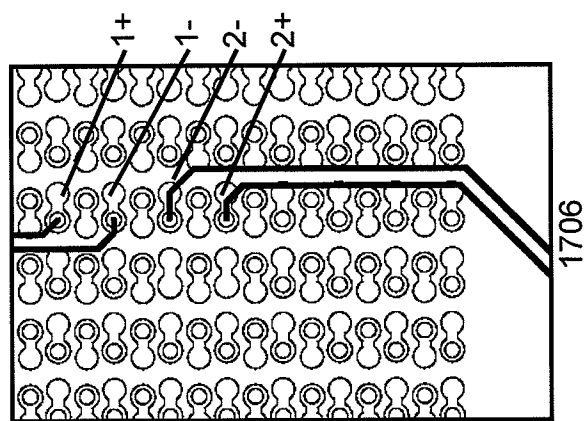
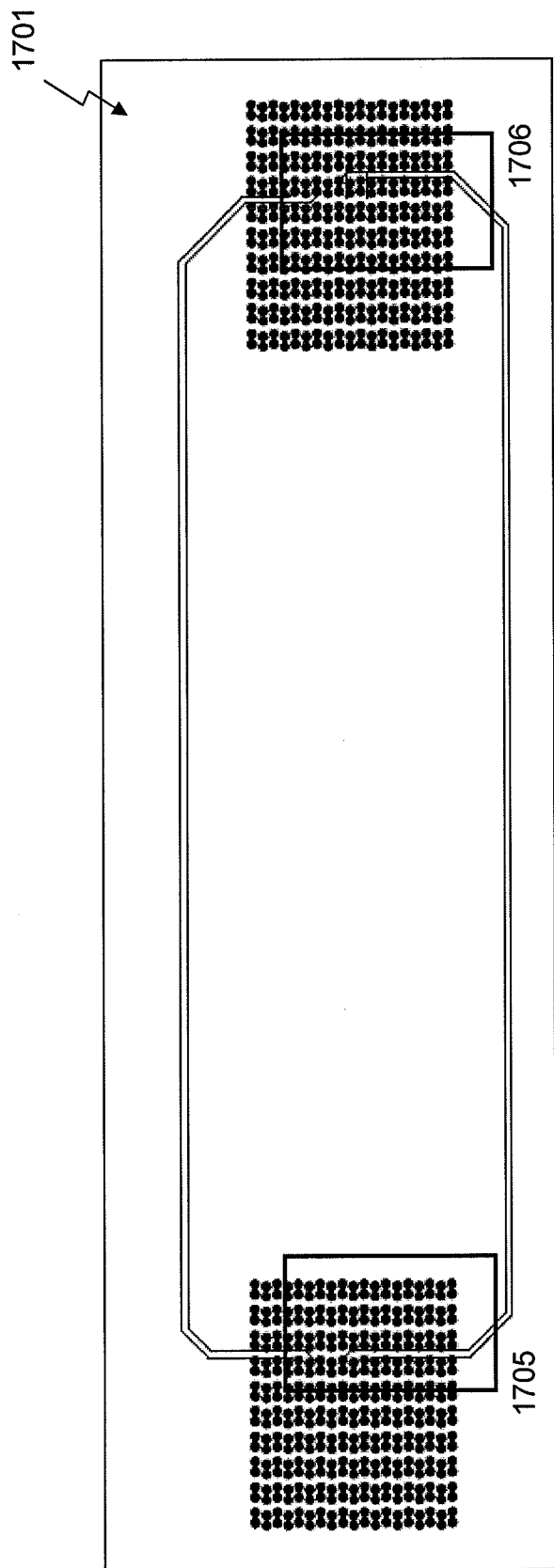


Figure 17b

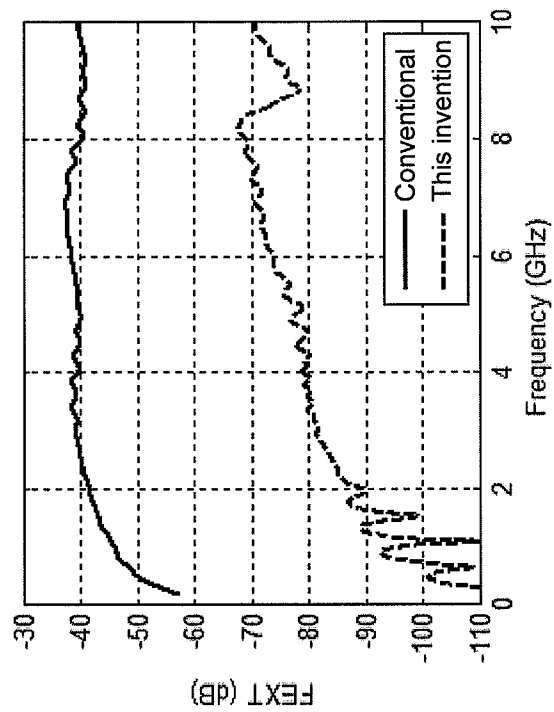


Figure 18

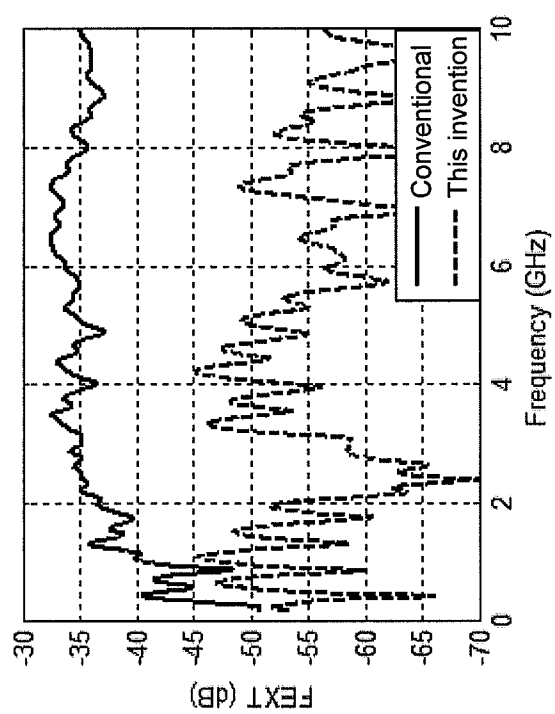


Figure 19

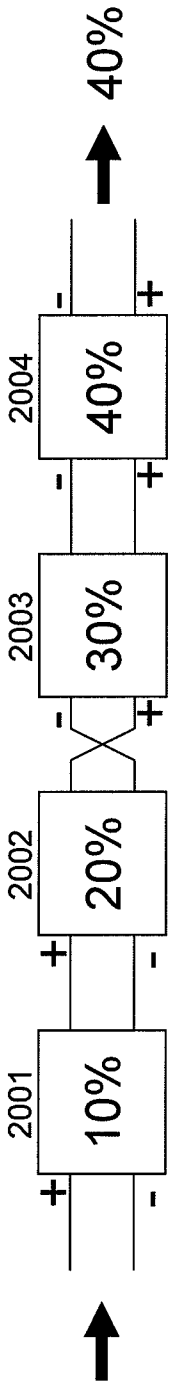


Figure 20a

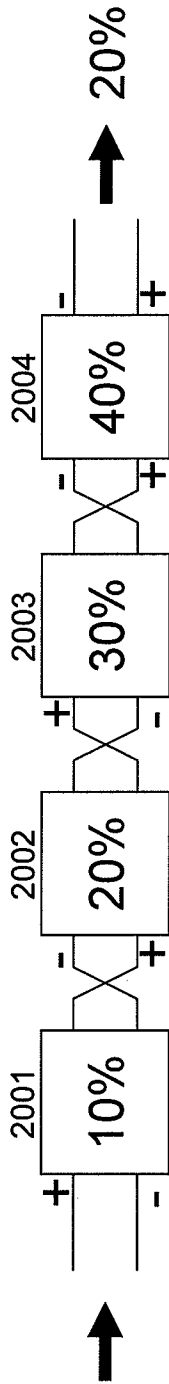


Figure 20b

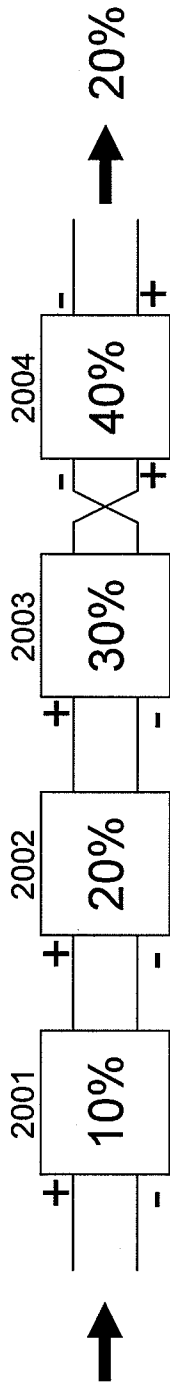


Figure 20c

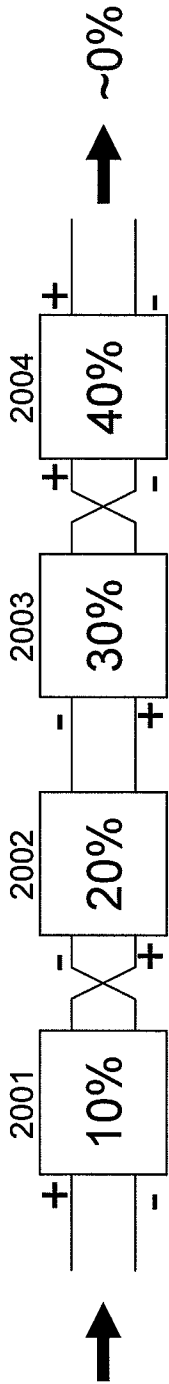


Figure 20d