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(54) Phase-shifting system for radiating elements of an antenna

Phasenverschiebungssystem für Strahlenelemente einer Antenne

Système de décalage de phase pour éléments de radiation d'une antenne

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Description

[0001] The present invention relates to a device for longitudinally displaced phase-shifting, including a dielectric material, used for phase-shifting radiating elements, or groups of radiating elements. The invention is intended to particularly be used for radiating elements that belong to antennas for base stations of cellular communication networks (GSM, UMTS, etc.), but also for any other type of application that implements phase-shifters. The purpose of phase-shifting is to adjust the direction of an antenna's main lobe, thereby attaining dynamic-tilt antennas, otherwise known as "adjustable-tilt antennas."

[0002] Phase-shifters are passive systems, meaning that they do not include electronic components, enabling them to apply a relative shift in phases between different access points of a radio frequency feed network. There are several major families of phase-shifting systems, depending on their mechanical operation method.

[0003] Firstly, there are rotating systems (such as described in US 6,850,130 and JP 09,246,846), in which one or more metallic parts are used to link various conductive lines. These metallic parts perform ad hoc coupling between the conductive lines, most commonly in the form of a contact-free connection, i.e. one in which a capacitive effect between two metallic parts couples the lines using RF.

[0004] However, the disadvantage of coupling lines together is that these systems may have difficulty achieving good performance over a wide frequency band without requiring that unwanted compromises be made with regard to coupling losses, and therefore to the overall effectiveness of the phase-shifting system. Another disadvantage of these systems is that it is difficult to add more of the conductive lines that will be linked to the radiating elements. Finally, this sort of system is significantly bulky.

[0005] Secondly, there are transverse movement systems (such as described in EP1215752), in which a material with a high dielectric constant and low dielectric loss is used to create relative phase-shifting between two radiating elements. The feed lines for radiating elements are installed serially. The movement is transversal with respect to the feed lines of the various radiating elements. Each phase shift is added to the total, until the final radiating element is being fed.

[0006] The disadvantage of this system is that each of these phase-shifters should be set in motion, although they are fairly distant physically from one another. Furthermore, these phase-shifters are placed along the primary longitudinal axis of the antenna, and the splitters are interspersed between them, which leads to the system being very long, particularly when significant phase-shifting is sought for the antenna (especially to 20° and beyond). This length makes it difficult to comply with the required tolerance.

[0007] Finally, there are longitudinal movement systems (such as described in US5,949,303 or WO/2002/035651), in which a material with a high dielectric constant and low dielectric loss is used to create relative phase-shifting between two radiating elements, or two groups of radiating elements, of an antenna. The material is inserted near the conductive line, which may be planar in structure, in the form of a stripline or microstrip. The propagation velocity of the signal that runs through this conductive line is reduced to a greater extent if the material's dielectric constant is higher, if the thickness of the dielectric material part is greater, and if the part is placed so as to cut off the lines of current running between the feed lines and the ground.

[0008] The major disadvantage of this system is that it requires a fairly high surface area to be activated, because the part made of dielectric material must move in a linear fashion from one end of the system to another, in a longitudinal direction. The limits to the part's movement thus limit the system's phase-shifting amplitude. Another disadvantage is that it is necessary to use multiple phase-shifters in order to achieve a complete feed-line structure for an antenna feed network.

[0009] The document WO/2002/035651 describes a monoblock phase-shifter, which moves as one piece and is made up of a single part made of dielectric material; it is given holes suitable for various conductive lines. This device does not allow the various conductive lines to be controlled independently.

[0010] The goal of the present invention is to eliminate the disadvantages found in the prior art, and particularly to disclose a low-loss longitudinal-movement phase-shifting system that is mechanically compact and stable, and that enables continuously varying phase-shifting.

[0011] The subject of the present invention is a phase-shifting system containing at least:

- a body which has at least one electrically conductive surface,
- an electrically conductive feed line placed on the body, including at least two segments which are parallel along a longitudinal axis and at least three access points,
- a movable dielectric device placed above the feed line.

[0012] In the invention, the device includes at least two distinct sections made of dielectric material, which are capable of moving independently along the longitudinal axis.

[0013] In a preferable embodiment, each section has areas located respectively at each end of the section, enabling impedance transformation.

[0014] In one variant, the impedance transformation areas possess recesses.

[0015] In another variant, the impedance transformation areas are separated by a central area made completely of dielectric material.

[0016] In yet another variant, the central areas of the sections have different lengths.

[0017] Preferably, the dielectric material selected is either a plastic material or a ceramic material.

[0018] Advantageously, the movement of the sections is achieved using a gear or a pivoting rod.

[0019] The system of the invention may additionally comprise a means for guiding the longitudinal movement of the sections.

[0020] In one embodiment of the invention, the feed line further includes a first portion for impedance transformation, and a second portion for dividing the current, with these portions being connected to the segments.

[0021] Another subject of the invention is an antenna that includes a phase-shifting system based on one of the preceding claims.

[0022] The phase-shifting system of the invention is a system that is passive (meaning that it contains no active electrical components) and reciprocal, meaning that it is suitable for functioning as either a "splitter" or a "combiner" with respect to the various access points.

[0023] The main advantage of the present invention is the ability to independently control the phase shifts between two radiating elements of an antenna. The system of the invention is thereby applicable to an unlimited number of radiating elements. Furthermore, it allows for the ability to attain non-linear phase shifts between the elements, meaning ensuring independent control of the phase shifts that are applied in pairs to the radiating elements.

[0024] Another advantage of the invention is that it makes possible a broad range of values for the antenna's inclination. In the system of the invention, it is even possible to attain high antenna beam inclinations, which may reach and even exceed 20°.

[0025] Furthermore, this system has the advantage of being modifiable, so that it can be adapted to be used along different frequency bands.

[0026] Consequently, the possible range of inclinations for the antenna's beam are limited only by the dielectric material used (the higher the material's dielectric constant, the wider the range of inclinations) and by the length of the antenna, which is naturally significant for panel antennas.

[0027] Other subjects, characteristics, and advantages of the present invention will become apparent from the following description of one particular embodiment, which naturally is given for illustrative purposes and is non-limiting, and from the attached diagram, in which:

- Figure 1 is a simplified diagram of the phase-shifting system of the invention,
- Figure 2 represents an exploded schematic view of a first embodiment of one phase-shifting system of the invention,
- Figure 3 shows the system of Figure 2, once assembled, in a position corresponding to the minimum phase shift of the antenna,
- Figure 4 is an oblique-perspective view of the body of the system of Figure 2,
- Figure 5 is a top view of the electrical feed line of the system in Figure 2,
- Figure 6 is an oblique-perspective view of the dielectric body of the system of Figure 2,
- Figure 7 is a schematic illustration of the movement of the dielectric sections using a gear,
- Figure 8 is a schematic illustration of the movement of the dielectric sections using a pivoting rod,
- Figure 9, analogous to Figure 3, shows the system of the invention in a centered position,

[0028] Figure 1 shows the phase-shifting system of the invention, including one electrical feed line **11** placed between two dielectric devices **12,** with the entire assembly being placed between two conductive bodies **13.**

[0029] In the embodiment of the invention depicted in Figures 2 and 3, the phase-shifting system includes the following components, overlaid along a direction A-A :

- a body **21** with a conductive surface;
- an electrical feed line **22** that comprises:
    - multiple conductive segments **22a-22e** which are parallel along direction B-B, intended to feed the radiating elements,
    - at least three access points, here for example as one central access point **23** and several access points **24a-24e** and **25a-25e** placed respectively on both ends of segments **22a-22e,**
    - a portion dedicated to the impedance transformation,
    - a portion dedicated to distributing power to the various access points;
    - a device **26** made of dielectric material that includes several independent sections **26a-26e** interspersed between the electrical line **22** and the conductive body **21;** through mechanical translation, the dielectric sections **26a-26e** may move along direction **B-B** so as to independently modify the respective coverage range of segments **22a-22e** of line **22;**
    - guiding means **27** and potentially additional mechanical parts to make it easier for the dielectric sections **26a-26e** to slide.

[0030] The body **21,** in the embodiment depicted in Figure 4, is made up of a conductive material, at least on its surface. For a "stripline" construction such as the one shown here, the body is equipped with two parallel conductive planes **21a** and **21b;** for a "microstrip" construction, a conductive line and a conductive plan acting as a "ground plane" are sufficient. The body **21** is constructed in the form of an aluminum block, which may have been bent, molded, or machined. The body may just as easily be created from other materials, such as brass, copper, or any other alloy with similar properties. The body may also be constructed in shapes other than the one depicted here.

[0031] The body **21** has an input **23** and outputs **24a-**

24e and **25a-25e** linked to a feed line **22.** The access points are shown here in the form of several connectors **24a-24e** and **25a-25e,** but they may also be constructed in the form of direct links to the radiating elements using coaxial cables, or by lengthening the segments of the "microstrip" or "stripline" feed line. The input **23** is depicted here in the central position, but it may also be placed on one of the sides of the body **21.** The minimum number of access points is therefore three, and only physical form-factor constraints may limit the number of them, except that this number is additionally limited to being an even or odd number.

[0032] The "stripline" electrical feed line **22,** depicted in Figure 5, is constructed as a single part, and is made up of several conductive segments **22a-22e.** The feed line **22** is obtained by perforating a brass plate 1 mm thick, but it may also be constructed with a different material with good electrical conductivity, as well as in the form of a printed circuit board.

[0033] In the form depicted here, the input **23** of the feed line **22** communicated with an access point area **50.** The portion **51** following the feed line **22** is used to enable proper impedance transformation between the input **23** and the number N of output connections available, with N ≥2 (here N = 10), such as with a progressive Klopfenstein impedance taper.

[0034] The portion **51** is extended by portion **52,** which is used to enable the splitting or combining of current for the various access points **50, 53a-53e** and **54a-54e.** Indeed, the conductive segments **22a-22e** do not necessarily have the same operating amplitude. In the present case, the outputs **53a-53, 54-54e** all have different amplitudes.

[0035] The conductive segments **22a-22e** are arranged in a rectilinear fashion, and are parallel to one another. During construction, an effort will be made to spread apart the segments **22a-22e** if possible, so as to minimize coupling between them. The width of the conductive segments **22a-22e** is suitable for attaining the desired input and output impedance, which is generally 60 Ohms. Typically, the conductive segments **22a-22e** may be about 7.35 mm wide for a thickness of 1 mm, when the "stripline" feed line **22** is etched between two ground planes **21a** and **21b** spaced 7 mm apart.

[0036] Figure 6 depicts the device **26** made entirely of dielectric material, which includes a fixed portion **60,** placed above the portion **51** of the electrical feed line **22,** and several sections **26a-26e** which are movable and can move independently of one another. Each dielectric section **26a-26e** includes a central area **61** made entirely of dielectric material; the central areas are identical, except for their length. The sections **26a-26e** are constructed of plastic, such as polyphenylene sulfide (PPS RYTON©), which has a dielectric constant of about 4 to 6. Although it is more expensive and requires greater precision, a ceramic material may also be used as a dielectric material whose dielectric constant ε_r is about 10.

[0037] Each dielectric section **26a-26e** includes two areas **62a** and **62b,** respectively located at each end of the sections **26a-26e,** which serve to transform impedance along the "stripline" feed line **22.** Impedance transition must occur between the part of the feed line **22** which is exposed to air and the part where the feed line **22** is completely between the body **21** and the central area **61** of one section **26a-26e** of the dielectric device **26.** In the embodiment shown here as an example, the impedance transformation function is handled by the creation of recesses **63** in the dielectric material at the end areas **62a, 62b** of each section **26a-26e** of the dielectric device **26.** These recesses **63** have been depicted here as rectangular holes, but they may naturally have any other form depending on the discounted result. For the purpose of achieving suitable impedance transformation between the part of the feed line 2 which is exposed to air, and the part where the feed line 2 is surrounded by dielectric material, the appropriate modification of the dielectric material of the sections **26a-26e** may be determined through calculation or simulation, based off an equivalence of the dielectric material made up of localized components, i.e. foreseen as the succession of discrete RLC components.

[0038] In another embodiment, the areas **62a, 62b** that handle impedance transition may be achieved using quarter-wave sections with different thicknesses, thereby allowing impedance transition between the part of the feed line **2** located in an environment made up of air, and the part of that line **2** whose environment is filled with dielectric material.

[0039] A significant advantage of the invention is that the phase-shifting system's dielectric device is made up by means of several sections **26a-26e.** The movement of each of these sections may be controlled separately, and in this manner, phase-shifting between elements is achieved at least for pairs of antenna radiating elements.

[0040] The guiding means **27** are made of a dielectric material, particularly the same material as that used for the dielectric device **26,** so that the conductive sections **26a-26e** of the electrical feed line **22** that they cross do not suffer any change of medium whatsoever. These means **27** may be constructed in multiple ways. In the embodiment disclosed here, struts **27a-27e** are used in order to guide the sections **26a-26e** when they slide longitudinally. A gear or rod, for example, may help the sections move; in this case, the speeds at which the linked sections move are identical. Another solution is to move the sections completely independently, such as by using stepper motors or independent linear actuators.

[0041] The dielectric sections **26a-26e** above the conductive segments **22a-22e** move while obeying rules that depend on the usage of the phase-shifting system In one specific situation, in which linear, progressive phase-shifting between the radiating elements of an antenna is necessary, such as 10°, then 20°, then 50°, etc., the sections **26a-26e** move independently, while maintaining a constantly moving distance between one another. For example, if section **26a** moves 20 mm, section **26b** must move 40 mm, section **26c** 60 mm, and so on.

[0042] The dielectric sections **26a-26e** may be moved in various ways. The dielectric sections **26a-26e** may, in particular, be moved in a synchronized fashion by means of a gear that includes an even number of toothed wheels, or by means of a pivoting rod.

[0043] Gear-based movement **70** is depicted in Figure 7. Shown here is a gear-based system **70,** comprising two toothed wheels **70a** and **70b** for moving the dielectric sections **71, 72** with respect to one another. A main dielectric section **71** is moved in one direction **73,** while a related section **72** moves in parallel with the section **71** and in the same direction **74** owing to the gears **70.**

[0044] Pivoting-rod-based movement is depicted in Figure 8. A rod **80** pivots along a direction of rotation **81** around a mechanical axle **82,** which is not fixed onto the dielectric device **26.** Each dielectric section **83a-83d** of the phase-shifting system is linked to the rod **80** by means of a pivot **84a-84d.** The pivots **84a-84d** must be capable of sliding to accompany the rotational movement of the rod **80.** This solution is simple to implement mechanically, but it may require that oblong holes be present in the body **1** so that the pivots **84a-84d** can slide.

[0045] The operation of the phase-shifting system of the invention has been studied in two different mechanical configurations:

- when the system **90** is in a centered position as depicted in Figure 9, and
- when the dielectric sections **26a-26e** are aligned and are shifted 20 mm away from one another, which corresponds to the equivalent position of a minimal antenna inclination, as depicted in Figure 3.

[0046] Simulation results show that the phase-shifting system of the present invention may advantageously be incorporated into a full antenna concept, to attain the same level of performance under current conditions of use, and furthermore, with the ability to reach antenna inclination angles much greater than current solutions.

[0047] The present invention is not limited to the embodiments that have been explicitly described; rather, it includes any variations and generalizations within the reach of a person skilled in the art.

Claims

1. A phase-shifting system, including at least

   - a body (21) which has at least one electrically conductive surface,
   - an electrically conductive feed line (22) placed on the body (21)and including at least two segments (22a-22e) which are parallel along a longitudinal axis B-B and at least three access points (23, 24a-24e, 25a-25e),
   - a movable dielectric device (26) placed on the upper side of the feed line (22),

   characterized in that the device (26) includes at least two distinct sections (26a-26e) made of dielectric material, which can move independently along the longitudinal axis B-B.

2. A system according to claim 1, in which each section (26a-26e) possesses areas (62a, 62b) located respectively at each end of the section (26a-26e), enabling impedance transformation.

3. A system according to claim 2, in which the impedance transformation areas (62a, 62b) possess recesses (63).

4. A system according to claim 3, in which the impedance transformation areas (62a, 62b) are separated by a central area (61) made entirely of dielectric material.

5. A system according to claim 4, in which the central areas (61) of the sections (26a-26e) are of different lengths.

6. A system according to one of the preceding claims; in which the sections (26a-26a) move by means of a gear (70) or a pivoting rod (80)

7. A system according to one of the preceding claims, in which the dielectric material is selected from among a plastic material and a ceramic material.

8. A system according to one of the preceding claims, further comprising guiding means (27) to guide the longitudinal movement of the sections (26a-26e).

9. A system according to one of the preceding claims, in which the feed line (22) further includes a first portion (51) for impedance transformation and a second portion (52) for dividing the current, with the portions bering connected to the segments (22a-22a).

10. An antenna comprising a phase-shifting system according to one of the receding claims.

Patentansprüche

1. Phasenschiebersystem, mindestens umfassend:

   - Einen Körper (21) mit mindestens einer elektrisch leitfähigen Oberfläche,
   - eine elektrisch leitfähige Versorgungsleitung (22), welche auf dem Körper (21) angeordnet ist und mindestens zwei Segmente (22a-22e), die parallel entlang einer Längsachse B-B angeordnet sind, und mindestens drei Zugangspunkte

(23, 24a-24e, 25a-25e) aufweist,
- eine bewegliche dielektrische Vorrichtung (26), welche an der oberen Seite der Versorgungsleitung (22) angeordnet ist,

dadurch gekennzeichnet, dass die Vorrichtung (26) mindestens zwei unterschiedliche Abschnitte (26a-26e) aus dielektrischem Material umfasst, welche sich unabhängig voneinander entlang der Längsachse -B-B) bewegen können.

2. System nach Anspruch 1, wobei jeder Abschnitt (26a-26e) jeweils an jedem Ende des Abschnitts (26a-26e) angeordnete Bereiche (62a, 62b) aufweist, welche eine Impedanztransformation ermöglichen.

3. System nach Anspruch 2, wobei die Impedanztransformations-Bereiche (62a, 62b) mit Aussparungen (63) versehen sind.

4. System nach Anspruch 3, wobei die Impedanztransformations-Bereiche (62a, 62b) durch einen ausschließlich aus dielektrischem Material bestehenden mittleren Bereich (61) voneinander getrennt sind.

5. System nach Anspruch 4, wobei die mittleren Bereiche (61) der Abschnitte (26a-26e) unterschiedliche Längen aufweisen.

6. System nach einem der vorstehenden Ansprüche, wobei die Bewegung der Abschnitte (26a-26e) durch ein Getriebe (70) oder eine Pendelstange (80) bewirkt wird.

7. System nach einem der vorstehenden Ansprüche, wobei das dielektrische Material unter einem Kunststoffmaterial oder einem keramischen Material ausgewählt wird.

8. System nach einem der vorstehenden Ansprüche, weiterhin umfassend Führungsmittel (27) zum Führen der Längsbewegung der Abschnitte (26a-26e).

9. System nach einem der vorstehenden Ansprüche, wobei die Versorgungsleitung (22) weiterhin einen ersten Teilbereich (51) für die Impedanztransformation und einen zweiten Teilbereich (52) für die Aufteilung des Stroms umfasst, wobei die Teilbereiche an die Segmente (22a-22e) angeschlossen sind.

10. Antenne mit einem Phasenschiebersystem gemäß einem der vorstehenden Ansprüche.

Revendications

1. Système de déphasage, comprenant au moins

   - un corps (21) qui présente au moins une surface électroconductrice,
   - une ligne d'alimentation électroconductrice (22) placée sur le corps (21) et comprenant au moins deux segments (22a à 22e) qui sont parallèles le long d'un axe longitudinal B-B et au moins trois points d'accès (23, 24a à 24e, 25a à 25e),
   - un dispositif diélectrique mobile (26) placé sur le côté supérieur de la ligne d'alimentation (22),

   caractérisé en ce que le dispositif (26) comprend au moins deux sections distinctes (26a à 26e) constituées d'un matériau diélectrique, qui peuvent se déplacer indépendamment le long de l'axe longitudinal B-B.

2. Système selon la revendication 1, dans lequel chaque section (26a à 26e) possède des zones (62a, 62b) situées respectivement à chaque extrémité de la section (26a à 26e), permettant ainsi une transformation d'impédance.

3. Système selon la revendication 2, dans lequel les zones de transformation d'impédance (62a, 62b) possèdent des évidements (63).

4. Système selon la revendication 3, dans lequel les zones de transformation d'impédance (62a, 62b) sont séparées par une zone centrale (61) entièrement constituée de matériau diélectrique.

5. Système selon la revendication 4, dans lequel les zones centrales (61) des sections (26a à 26e) sont de longueurs différentes.

6. Système selon l'une des revendications précédentes, dans lequel les sections (26a à 26e) se déplacent au moyen d'un engrenage (70) ou d'une tige pivotante (80).

7. Système selon l'une des revendications précédentes, dans lequel le matériau diélectrique est choisi parmi un matériau plastique et un matériau céramique.

8. Système selon l'une des revendications précédentes, comprenant en outre des moyens de guidage (27) pour guider le mouvement longitudinal des sections (26a à 26e).

9. Système selon l'une des revendications précédentes, dans lequel la ligne d'alimentation (22) comprend en outre une première partie (51) pour la trans-

formation d'impédance et une deuxième partie (52) pour diviser le courant, les parties étant connectées aux segments (22a à 22e).

10. Antenne comprenant un système de déphasage selon l'une des revendications précédentes.

FIG_1


12
25a
13

FIG_2

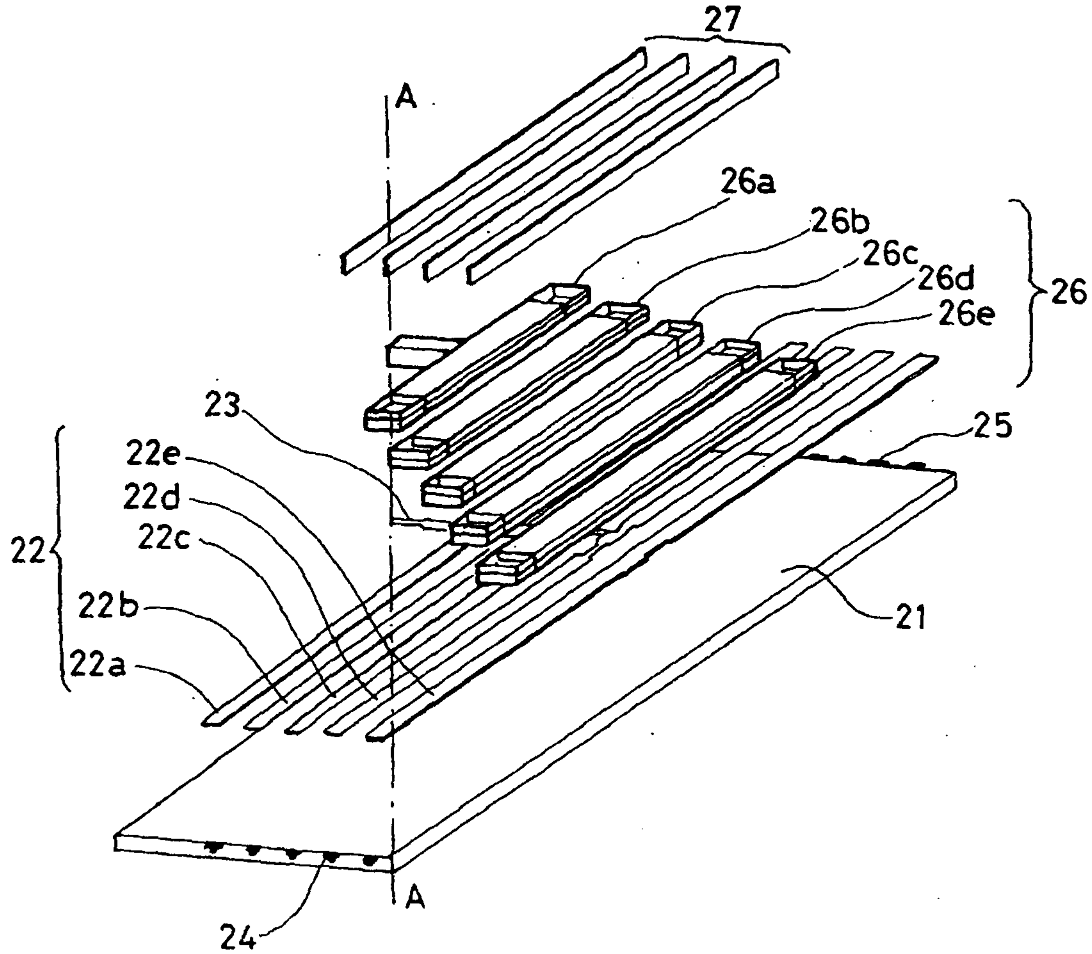

27
A
26a
26b
26c
26d
26e
26
23
25
22e
22d
22c
22
22b
22a
21
A
24

FIG_3

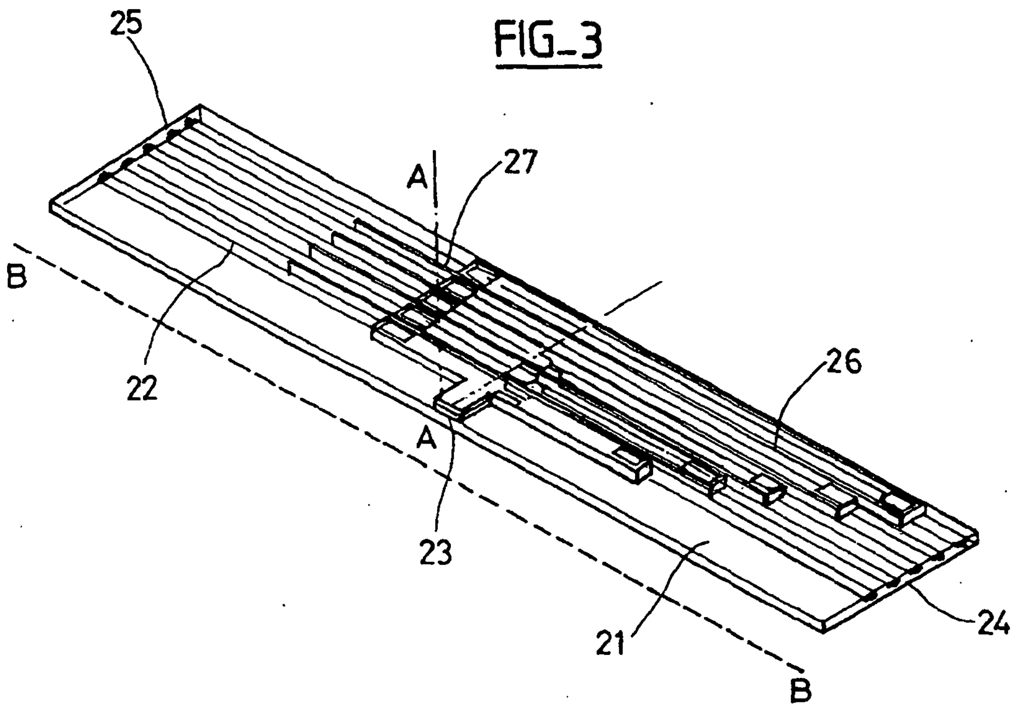


FIG_4

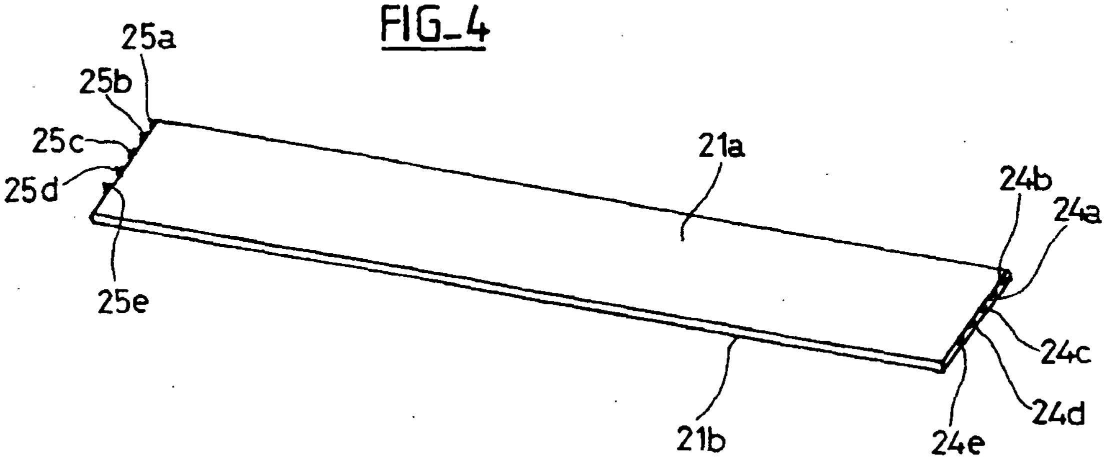


FIG_5

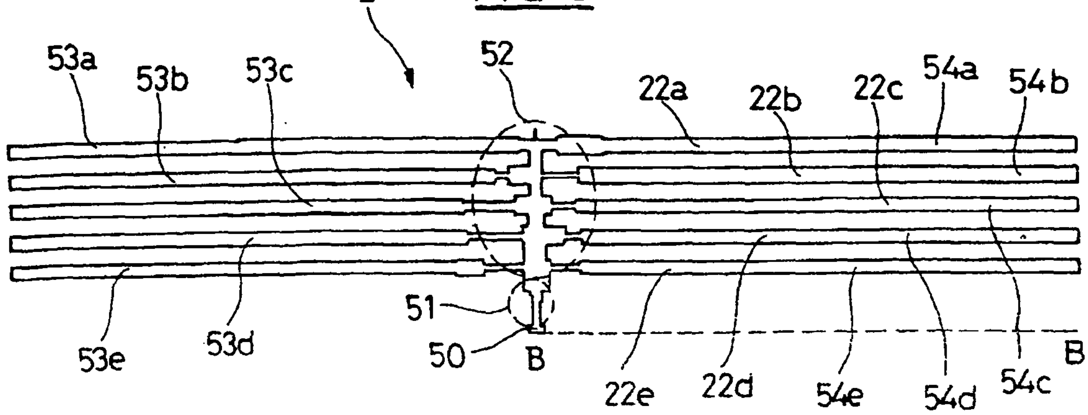


FIG_6

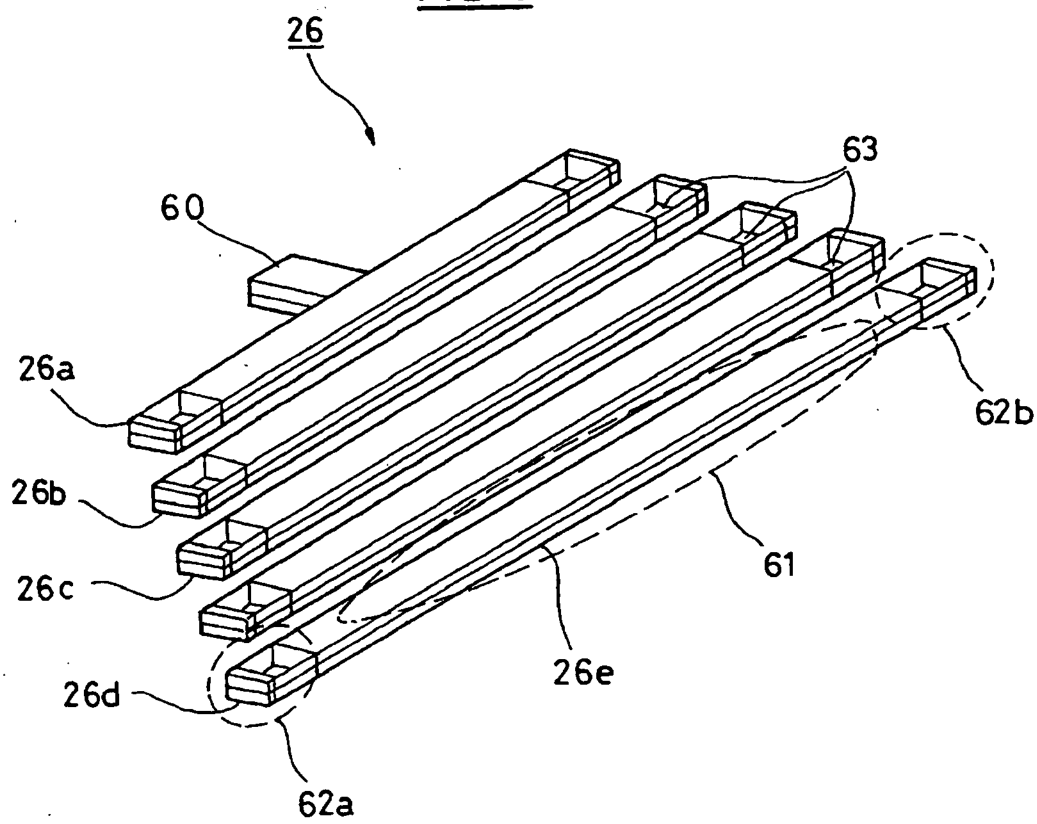


FIG_7

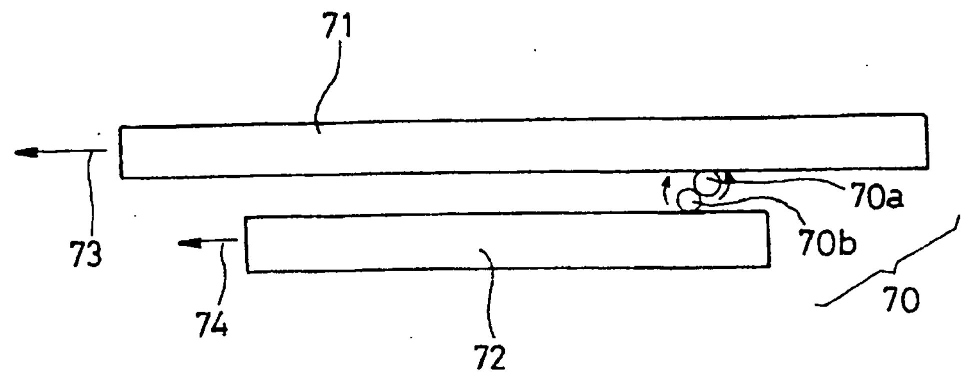


FIG_8

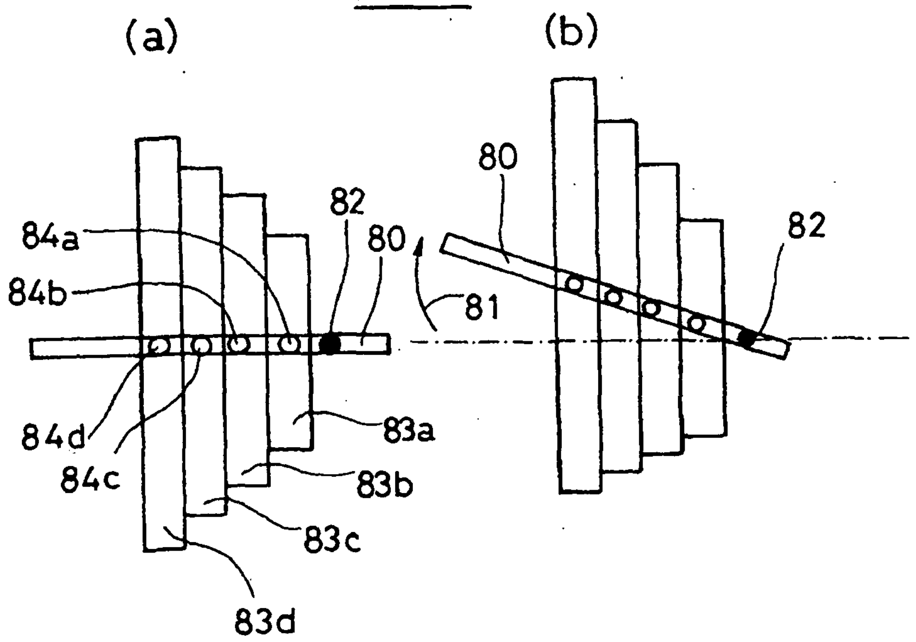
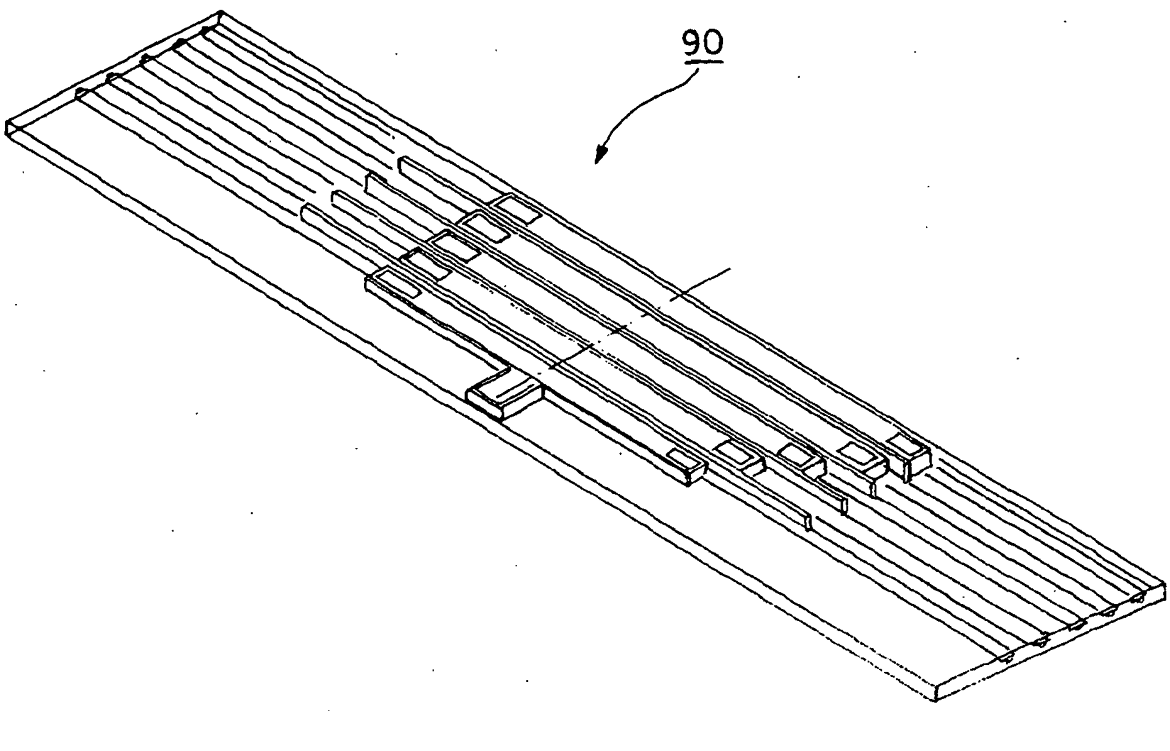


FIG_9



REFERENCES CITED IN THE DESCRIPTION

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