(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 923 217 A1

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
**21.05.2008 Bulletin 2008/21**

(51) Int Cl.:
***B41J 2/09*** *(2006.01)*

(21) Application number: **06124195.6**

(22) Date of filing: **16.11.2006**

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

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(54) **Improvements in or relating to continuous ink jet printers**

(57) The invention describes a printhead for a continuous inkjet printer in which one of the deflector plates used to deflect ink droplets is extended to overlie the gutter. The gutter, itself, is preferably charged in the same manner as the other deflector plate and thus becomes part of the charge field.

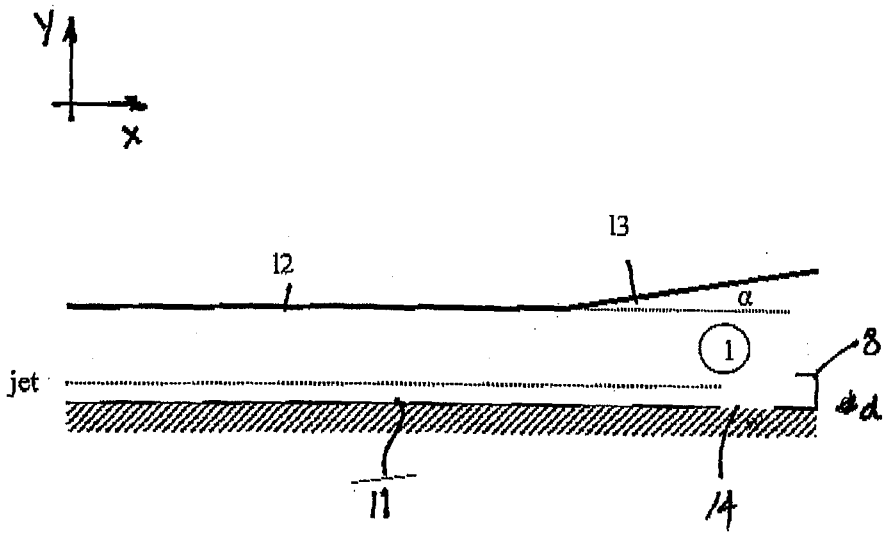


FIGURE 4

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## Description

### Field of the Invention

**[0001]** This invention relates to a continuous inkjet (CIJ) print head.

### Background to the Invention

**[0002]** As is well known, CIJ printing involves the formation of electrically charged drops from a jet of ink, and the subsequent deflection of the charged drops by an electric field to produce an image on a print medium.

**[0003]** Electrically conducting ink is forced through a nozzle. As a result of surface tension, the ink jet breaks up into drops. In a CIJ print head, a controlled sequence of drops, each with identical drop volume and with constant separation between adjacent drops, can be formed by modulating the jet in a controlled fashion. This can be achieved by modulating the ink pressure, or the ink velocity relative to the nozzle, in a sinusoidal manner at fixed frequency and amplitude.

**[0004]** A range of options and techniques are known to those skilled in the art to induce pressure modulation, velocity modulation or a combination of both, so that uniform drop sequences are obtained. The most widespread of these known techniques is ultrasonic agitation using piezo-electric crystals, by which electrical energy is converted into mechanical energy.

**[0005]** Whatever the form of modulation employed, charge is induced on individual ink drops by means of a charge electrode that is located in the vicinity of the position at which the drops separate from their jet. Charge flows onto the conducting jet through capacitive coupling between electrode and jet. Desired levels of charge are induced on drops by applying a voltage to the electrode at the time the drop separates from the jet. A range of charge voltages is used to achieve different degrees of deflection of the individual drops. The charge electrode voltage is updated whenever a drop separates from its jet. Hence electrode and jet are modulated at the same frequency, and great care is taken to ensure that a suitable phase relationship is maintained between the two signals so that the correct charge voltage is present at the time of drop separation.

**[0006]** After charging, the ink drops travel through a constant electric field whose field lines are substantially perpendicular to the jet. The field is typically produced by applying a high voltage to a parallel-plate capacitor through which the drops travel. Charged drops are deflected by an amount that scales with the charge on the drops. Uncharged drops are not deflected and fall into a vacuum re-flow, often referred to as gutter or catcher, for re-use of un-printed ink. The technique described here enables the printing of an image, consisting of a plurality of drops, on a medium.

**[0007]** Clearly the manner in which the charged drops interact with the deflecting field, is extremely important and this will now be explained in broad terms with reference to Figures 1 to 3 of the accompanying drawings.

**[0008]** Figure 1 illustrates a first form of conventional deflector-plate configuration. After drop formation and charging, the stream 5 of ink drops travels through an electric field that is produced by two charged parallel plates 6 & 7 separated by a spacing s of typically 3-5mm. These plates 6 & 7 are often referred to as deflector plates. The drop-producing device (not shown) is typically arranged such that un-deflected drops travel parallel and as close as possible to one of the deflector plates (in this case the lower plate 6). Such a configuration allows deflection in one direction only (positive y direction in Figure 1), with a maximum deflection, measured at the right-hand edges of the deflector plates, that is slightly less than the plate separation d.

**[0009]** Often the upper deflector plate 7 is set to a high positive voltage (typically a few kV) and the lower deflector plate 6 is set to ground. This requires the drops to be charged negatively. Uncharged drops are collected by a gutter 8 that is positioned adjacent to the exit (right-hand) end of the lower deflector plate 6.

**[0010]** The gutter is typically formed from stainless steel and may be of a circular or rectangular design. The section of the gutter edge nearest the top deflector plate 7 is normally very narrow (typically 100$\mu$m). This enables the use of a large deflection range, close to the plate separation d, as un-printed drops and least-deflected drops will follow similar trajectories.

**[0011]** Referring now to Figure 2, the deflector plate configuration depicted uses an angled top deflector plate 10 to take account of the fact that the deflection in the y direction increases with the distance a drop will have travelled in x direction, between the deflector plates. This configuration is attractive as the deflection to which a drop is subjected varies quadratically with the distance travelled, but only varies linearly with the inverse of the plate separation d.

**[0012]** The disadvantage of the configuration shown in Figure 2 is that the electric field is no longer homogeneous. Hence, the force acting on a charged drop not only depends on its charge but also on its position.

**[0013]** Compared to the configuration shown in Figure 1, the configuration shown in Figure 2 can reduce the overall accuracy with which drops can be positioned on a print medium. The x component of the electric field is non-zero and changes with y position, which means that the x component of the velocity is affected by the electric field. Strongly deflected drops experience a larger deceleration in the x direction than weakly deflected ones. This can result in image artefacts at high print speed.

**[0014]** Figure 3 shows yet a further deflector plate configuration in which the drops first travel through a parallel section 12, which provides a homogeneous field, followed by a sloped section 13 to account for the increased deflection after some distance travelled.

**[0015]** Regardless of the deflector plate configuration, it is desirable to place the gutter as close as possible to the deflector plates (the lower deflector plate in Figures 1 to 3). This is because drops slow down due to aerodynamic drag, which degrades print quality in particular if the drops are small. In general it is desirable that drops become available for printing soon after they have travelled through the electric field and are no longer accelerated.

**[0016]** In commercial CIJ applications, a value for the maximum throw distance of a printer is often recommended. It is defined as the maximum allowable separation between the print head and the print medium, above which the print quality degrades. It will be appreciated that relatively large throw distances can be achieved with a print head in which the gutter is small and placed very close to the deflector plates.

**[0017]** Whilst positioning the gutter close to the deflector plates increases the throw distance, a resulting disadvantage is that the presence of the gutter influences the electric field in the vicinity of the edge of the deflector plates (illustrated as region 1 in Figures 1 to 3) in a way that reduces drop placement accuracy and introduces image artefacts. Referring to Figures 1 to 3, the gutter 8 is conducting and set to ground. Hence, a stray field forms between the edge of the upper deflector plate and the gutter. This can be better understood with reference to the simulation shown in Figure 5.

**[0018]** Figure 5 shows a 2-dimensional electrostatic model in which the main components of the deflection area of a printhead are approximated by blocks. The two blocks representing the ground plate and the gutter, are set to ground potential. The deflector plate, the slope of which is approximated by a series of stepped blocks, is set to a positive potential. Modelling was carried out using a Java applet obtained from www.falstad.com. Whilst this does not yield absolute values, it does allow the relative strength and direction of the electric field to be visualised.

**[0019]** Referring to Figure 5, it can be seen that the x component of the electric field in region 1 is comparable to its y component for medium-deflected drops. For strongly deflected drops with a trajectory that comes very close to the right edge of the top deflector plate, the x component of the electric field in region 1 exceeds its y component. As discussed above, a field distribution of this kind reduces drop placement accuracy and it introduces image artefacts as the x component of the velocity is affected by the electric field in a manner that depends on drop charge.

**[0020]** It is an object of the invention to provide a method of, and or means for, effecting drop charging and/or deflection in a continuous inkjet printer which will go at least some way in addressing the drawbacks set forth above, or which will at least offer a novel and useful alternative.

**Summary of the Invention**

**[0021]** Accordingly, in one aspect, the invention provides a printhead for a continuous inkjet printer, said printhead including:

a droplet generator operable to generate a stream of ink droplets;
a charging electrode operable to electrically charge at least some of said droplets;
a gutter positioned to receive selected droplets; and
a pair of spaced deflector plates operable to create an electric field which interacts with charged droplets to deflect said charged droplets,

said printhead being characterized in that said gutter is positioned and an electric potential applied to it so as to contribute to the creation of a substantially homogeneous electric field.

**[0022]** Preferably said gutter is mounted on a substantially common plane with one of said deflector plates.

**[0023]** Preferably said gutter is separated from said one of said deflector plates by a dielectric.

**[0024]** Preferably said dielectric has a dielectric constant (ε) in the range 2 to 4.

**[0025]** Preferably both said gutter and said one of said deflector plates are mounted on a common based provided by said dielectric.

**[0026]** Preferably said gutter and said one of said deflector plates are set to ground potential.

**[0027]** Preferably the other of said deflector plates is set to a positive potential.

**[0028]** Preferably the other of said deflector plates is arranged to at least partially overlie said gutter.

**[0029]** In a second aspect, the invention provides a printhead for a continuous inkjet printer, said printhead including:

a droplet generator operable to generate a stream of ink droplets along an ejection axis;
a charging electrode operable to electrically charge at least some of said droplets; a pair of spaced deflector plates operable to create an electric field which interacts with charged droplets to deflect said charged droplets, and
a gutter positioned further along said ejection axis than said pair of deflector plates to capture selected one of said droplets,

said printhead being characterized in that said gutter is positioned adjacent one of said deflector plates and at least partially over-lied by the other of said deflector plates when viewed along a line perpendicular to said ejection axis.

**[0030]** Preferably said gutter is mounted on a common plane with one of said deflector plates but separated there-from by a dielectric.

**[0031]** In a third aspect the invention provides a printhead including:

a droplet generator operable to generate a stream of ink droplets along an ejection axis;

a charging electrode operable to electrically charge at least some of said droplets;

a pair of spaced deflector plates operable to create an electric field which interacts with charged droplets to deflect said charged droplets, and

a gutter positioned further along said ejection axis than said pair of deflector plates to capture selected one of said droplets,

said printhead being characterized in that said gutter is positioned adjacent one of said deflector plates, in substantially the same plane as said one of said deflector plates, but is spaced from said one of said deflector plates by a dielectric.

**[0032]** Many variations in the way the present invention can be performed will present themselves to those skilled in the art. The description which follows is intended as an illustration only of one means of performing the invention and the lack of description of variants or equivalents should not be regarded as limiting. Wherever possible, a description of a specific element should be deemed to include any and all equivalents thereof whether in existence now or in the future.

## Brief Description of the Drawings:

**[0033]** The background to the invention, and a working embodiment of the invention, is described with reference to the accompanying drawings in which:

| | |
|---|---|
| Figures 1 to 3 | show various forms of printhead arrangement used in prior art forms of CIJ printer; |
| Figure 4: | shows a printhead arrangement for a CIJ printer incorporating the various aspects of the present invention; and |
| Figures 5 & 6: | show 2-dimensional electrostatic models of, respectively, a prior art printhead arrangement and a printhead arrangement according to the invention. |

## Description of Working Embodiments

**[0034]** The embodiments presented in this invention overcome the issue of reduced print quality due to non-homogeneous fields that form in printhead configurations with sloped deflector plates; and due to stray fields from the gutter. An example of an embodiment according to the invention is shown in Figure 4. A 2-dimensional electrostatic simulation of this embodiment is shown in Figure 6.

**[0035]** The upper deflector plate has a parallel section of length l2 and a sloped section of length 13 at an angle $\alpha$ to the plane of section 12. The lower deflector plate has a length l1 and may extend beyond the left edge of the upper deflector plate.

**[0036]** In this embodiment, typical values for the above parameters are as follows: l1=30mm, l2=20mm, l3=12mm and $\alpha$ =10 to 11°.

**[0037]** Although the right-hand edge of the lower deflector plate in Figure 4 extends into the sloped region of the upper deflector plate, this invention is not limited to such a form and also includes embodiments in which the right-hand edge of the lower deflector plate falls into the parallel region.

**[0038]** Adjacent to the lower deflector plate, there is a spacer 14 of width w and depth d, consisting of a dielectric material with dielectric constant $\varepsilon$, or of a plurality of dielectric materials, each with a separate dielectric constant $\varepsilon$. In this example, typical values for the above parameters are as follows:
w=8mm, d=10mm and $\varepsilon$=2 to 4.

**[0039]** The optimised values for w, d, and $\varepsilon$ may be substantially different from the above for embodiments with different values for l1, l2 and l3 and $\alpha$. This is particularly the case for the dielectric constant $\varepsilon$. Furthermore, the left edge of the lower deflector plate in Figure 4 may extend to the left beyond the edge of the upper deflector plate, typically by a few millimetres.

**[0040]** In order to ease manufacture of the embodiment, the dielectric material(s) may extend partially or substantially completely underneath the lower deflector plate 11 and the gutter 8 to provide a base fixture or mounting for both the lower deflector plate and the gutter.

**[0041]** It is an essential feature of one aspect of the invention that the sloped section 13 of the upper deflector plate partially or fully overlaps the gutter 8. As can be seen from the simulation illustrated in Figure 6, the combination of the section 13 overlapping the gutter 8, and the provision of a dielectric material between the gutter 8 and the bottom electrode 11, results in a relatively homogeneous electric field between the upper deflector plate and the bottom plate/gutter combination.

**[0042]** The embodiment shown in Figure 4 has the following advantages over conventional designs as shown in figures 1-3:

1. The stray field in the vicinity of the right edge of the upper deflector plate and the gutter is reduced as the gutter is partially or fully overlapped by the sloped section of the upper deflector plate. Depending on the exact shape of the gutter body, the lowest overall stray field is obtained if the upper deflector plate edge is aligned to the right-hand edge of the gutter.

2. Effectively, the gutter forms part of the lower deflector plate. Compared to conventional designs as shown in Figures 1-3, this reduces the overall length of the drop trajectories, resulting in improved throw distance.

3. In the absence of a dielectric material, if the lower deflector plate were to extend to the gutter, the elec-

tric field in the sloped region would reduce gradually to the right due to the increased separation between the plates as in conventional designs shown in Figures 2 & 3. However, with a dielectric spacer in place in combination with an overlapped gutter, the constant and homogeneous field present in the parallel section can substantially be maintained in the sloped region despite the increasing separation between plates, provided the angle $\alpha$ is not too large. Optimised values for width w, depth d and dielectric constant $\varepsilon$ exemplified above for deflector plate dimensions l1, l2, l3 and angle $\alpha$ result in a substantially constant and homogenous electric field both in the parallel and sloped section. These values can be determined through theoretical modelling with commercial finite-element analysis software package. These can be used to solve the Poisson equation for the arrangement and dimensions in Figure 4 under the boundary conditions of two fixed voltages applied to the upper deflector plate and the lower deflector plate and gutter, respectively.

**[0043]** Modifications of the specific embodiment described here can be derived by those skilled in the art, based on the principles and findings presented in this invention. In particular, but by no means solely, the slope of the angled section 13 of the upper deflector plate in Figure 4 may not be constant but increase gradually in the x direction.

## Claims

**1.** A printhead for a continuous inkjet printer, said printhead including:

a droplet generator operable to generate a stream of ink droplets;
a charging electrode operable to electrically charge at least some of said droplets;
a gutter positioned to receive selected droplets; and
a pair of spaced deflector plates operable to create an electric field which interacts with charged droplets to deflect said charged droplets,

said printhead being **characterized in that** said gutter is positioned and an electric potential applied to it so as to contribute to the creation of a substantially homogeneous electric field.

**2.** A printhead as claimed in claim 1 wherein said gutter is mounted on a substantially common plane with one of said deflector plates.

**3.** A printhead as claimed in claim 1 or claim 2 wherein said gutter is separated from said one of said deflector plates by a dielectric with a dielectric constant $\varepsilon$ or a plurality of dielectrics, each with a separate dielectric constant $\varepsilon$.

**4.** A printhead as claimed in claim 3 wherein said dielectric has a dielectric constant ($\varepsilon$) in the range 2 to 4.

**5.** A printhead as claimed in claim 3 or claim 4 wherein both said gutter and said one of said deflector plates are mounted on a common based provided by said dielectric.

**6.** A printhead as claimed in any one of the preceding claims wherein said gutter and said one of said deflector plates are set to ground potential.

**7.** A printhead as claimed in claim 6 wherein the other of said deflector plates is set to a positive potential.

**8.** A printhead as claimed in any one of claims 2 to 7 wherein the other of said deflector plates is arranged to at least partially overlie said gutter.

**9.** A printhead for a continuous inkjet printer, said printhead including:

a droplet generator operable to generate a stream of ink droplets along an ejection axis;
a charging electrode operable to electrically charge at least some of said droplets;
a pair of spaced deflector plates operable to create an electric field which interacts with charged droplets to deflect said charged droplets, and
a gutter positioned further along said ejection axis than said pair of deflector plates to capture selected one of said droplets,

said printhead being **characterized in that** said gutter is positioned adjacent one of said deflector plates and at least partially over-lied by the other of said deflector plates when viewed along a line perpendicular to said ejection axis.

**10.** A printhead as claimed in claim 9 wherein said gutter is mounted on a common plane with one of said deflector plates but separated there-from by a dielectric with a dielectric constant $\varepsilon$ or a plurality of dielectrics each with a separate dielectric constant $\varepsilon$.

**11.** A printhead for a continuous inkjet printer including:

a droplet generator operable to generate a stream of ink droplets along an ejection axis;
a charging electrode operable to electrically charge at least some of said droplets;
a pair of spaced deflector plates operable to create an electric field which interacts with charged droplets to deflect said charged droplets, and
a gutter positioned further along said ejection

axis than said pair of deflector plates to capture selected one of said droplets,

said printhead being **characterized in that** said gutter is positioned adjacent one of said deflector plates, in substantially the same plane as said one of said deflector plates, but is spaced from said one of said deflector plates by a dielectric with a dielectric constant ε or a plurality of dielectrics, each with a separate dielectric constant ε.

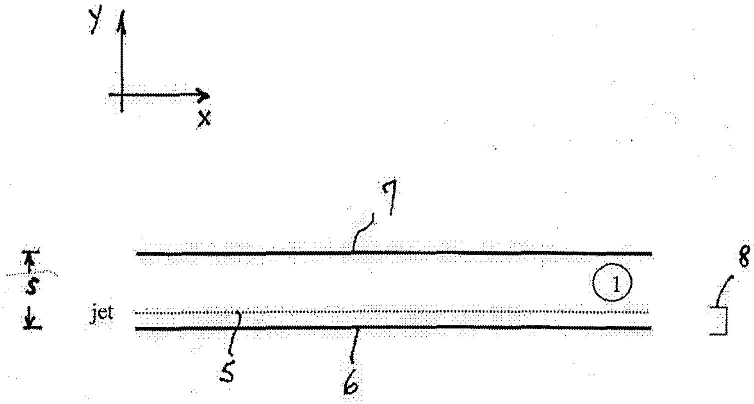


FIGURE 1 (PRIOR ART)

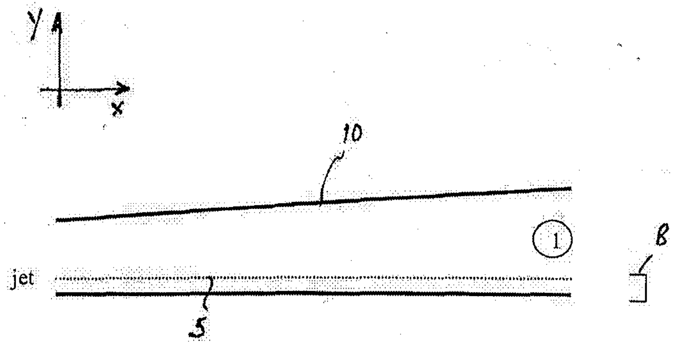


FIGURE 2 (PRIOR ART)

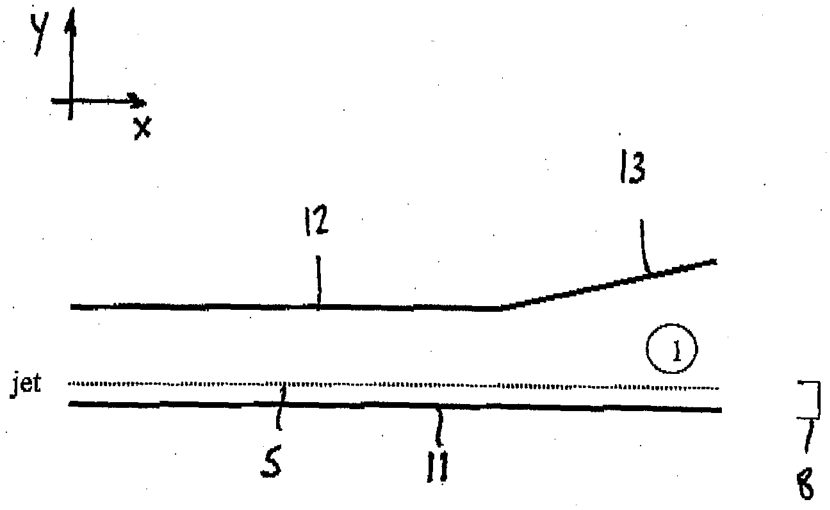


FIGURE 3 (PRIOR ART)

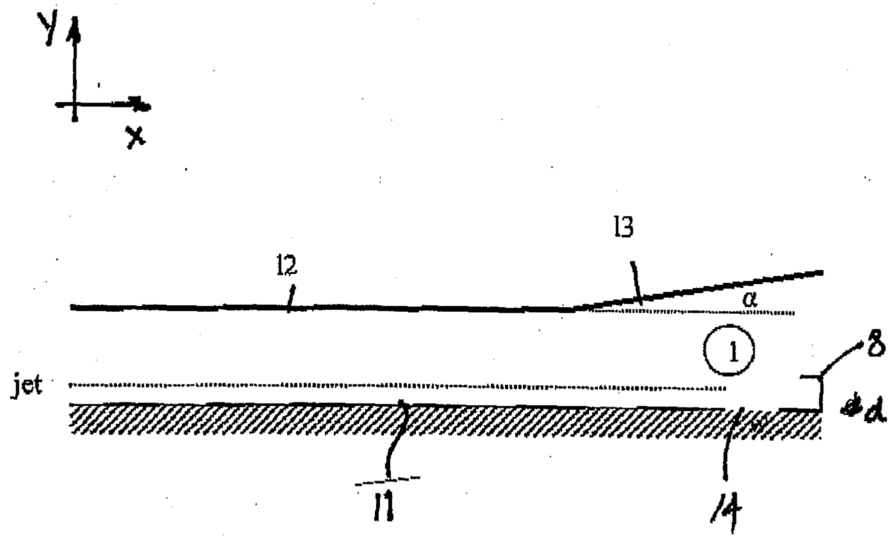


FIGURE 4

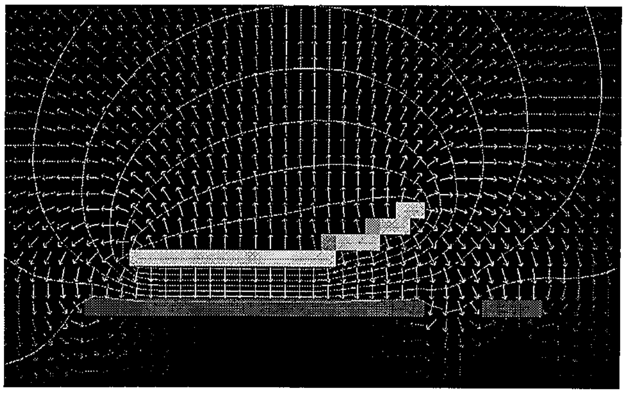

FIGURE 5

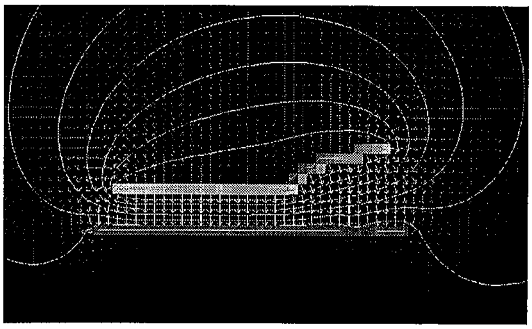

FIGURE 6

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# EUROPEAN SEARCH REPORT

Application Number
EP 06 12 4195

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (IPC) |
|---|---|---|---|
| X | US 4 314 258 A (DONAHUE JOHN W ET AL) 2 February 1982 (1982-02-02) | 1-7,11 | INV. B41J2/09 |
| Y | * column 4, line 48 - column 5, line 5 * ----- | 8-10 | |
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TECHNICAL FIELDS SEARCHED (IPC)

B41J

The present search report has been drawn up for all claims

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| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| The Hague | 19 April 2007 | Gavaza, Bogdan |

CATEGORY OF CITED DOCUMENTS

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