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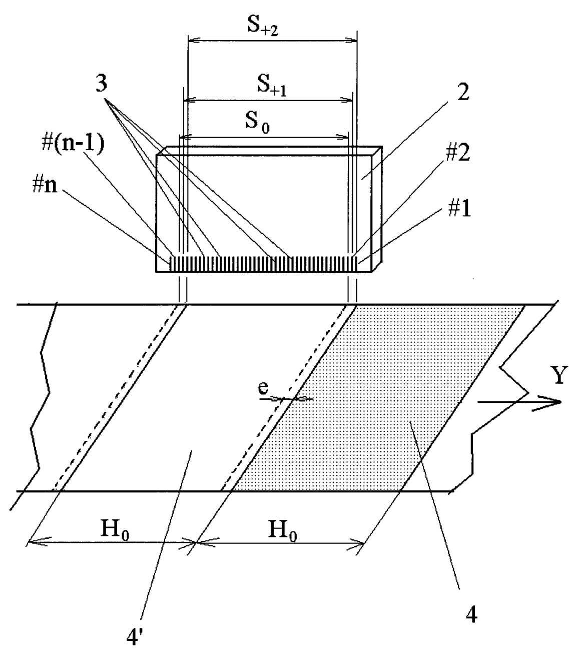
(54) A method for printing on media

(57) A method for printing on media comprises performing a plurality of printing swaths with at least one printhead (2), maintaining the media (1) stationary while printing each swath and advancing the media (1) between swaths, said printhead being provided with an array of dot forming elements (3). After at least some of the swaths said method comprises the steps of:

(a) advancing the media (1) to a nominal position;
(b) determining the error in the position of the media with respect to said nominal position;
(c) depending on said error, selecting a subset (S_0, S_{+1}, S_{-1}, S_{+2}, S_{-2}, S_{+3}, ...) of said array of dot forming elements (3); and
(d) printing the next swath using dot forming elements (3) from said selected subset (S_0, S_{+1}, S_{-1}, S_{+2}, S_{-2}, S_{+3}, ...).

It allows the reduction of defects due to media positioning errors.

FIG. 2b



EP 1 410 914 A1

Description

[0001] The present invention relates to a method for printing on media and to an incremental printing apparatus.

[0002] In an incremental printing apparatus, for example an inkjet printer, printing is carried out in successive swaths of at least one printhead on a printing media such as paper.

[0003] Each printing swath is performed while the paper remains stationary, and the paper is advanced between each two swaths.

[0004] For example, in each printing swath the printhead may travel along a so-called scan axis, at right angles to the direction of advance of the paper, and eject dots of ink towards the paper by means of an array of nozzles which are arranged in the printhead at least along the direction of advance of the paper.

[0005] As a consequence, the printhead forms in each swath a strip or pattern of ink dots on a length of media equal to the length of the array of nozzles in the direction of advance of the paper. This length will be referred to hereinafter as "swath height".

[0006] Each printed strip has the dimension of the swath height and corresponds to a fraction of the input image data; the complete image is formed on the media by the juxtaposition of successive strips.

[0007] In single pass printing mode, the swaths and the strips printed in each swath are adjacent to each other, while in multipass printing mode the swaths and printed strips are partly overlapped with each other, such that the image is formed by the superposition of ink dots from several passes.

[0008] One aspect of the process that influences the printing quality is the advance of the media. In order to avoid defects, the advance in each swath has to correspond to the swath height, such that in single-pass printing mode each printed strip starts exactly where the previous strip finishes; however, several parameters such as mechanical tolerances in the driving system or media slippage may cause errors in the media advance, i.e. the advance may be shorter or longer than the nominal swath-height advance, especially if this nominal advance is relatively large.

[0009] Furthermore, the advance error may accumulate swath after swath.

[0010] Errors in the media advance will cause defects in the plot. For example, in single-pass printing mode a white streak may appear between swaths if the media underadvances, or a dark region may build up in case of overadvance and thus undesired overlapping between two swaths; these defects, generally referred to as "banding", may be visible in the final printed image. Defects caused by errors in the media advance may be especially visible in single pass printing mode.

[0011] Known solutions proposed for minimising banding due to errors in the media advance generally aim at adjusting the advance of the media itself or the physical position of the printhead, thus involving relatively complex mechanical systems and requiring operations that slow down the printing operation.

[0012] Co-owned patent US5825378 proposes a calibration system in order to compensate the media advance errors due to parameters having a cyclic effect, such as eccentricities in the driving mechanisms; however, this document does not address the problem of swath-to-swath differences in the advance of the media, such as those caused by media slippage.

[0013] On the other hand, co-owned European patent application EP1197916A2 deals with banding defects related to the performance of the printhead, e.g. caused by aiming errors near the ends of the nozzle array, especially in color printing; according to this document, these errors cause banding because they generate a difference between the nominal printhead height and the actual printed swath height. This situation is different from the media advance problem addressed in the present invention, in which the printed swath height coincides with the nominal printhead height, but it is printed displaced from its theoretical position.

[0014] The two cited documents provide detailed explanations of parameters and phenomena related to banding errors, and are hereby incorporated by reference.

[0015] According to an aspect, the present invention provides a method for printing on media comprising performing a plurality of printing swaths with at least one printhead, maintaining the media stationary while printing each swath and advancing the media between swaths, said printhead being provided with an array of dot forming elements, wherein after at least some of the swaths said method comprises the steps of:

(a) advancing the media to a nominal position;
(b) determining the error in the position of the media with respect to said nominal position;
(c) depending on said error, selecting a subset of said array of dot forming elements (3); and
(d) printing the next swath using dot forming elements from said selected subset.

[0016] This correction system is simpler and faster than mechanical adjustment of the position of the media or of the printhead; and it allows high throughput and long advance printmodes with fairly good printing quality.

[0017] As a consequence, it also allows a reduction of the mechanical constraints for media advance.

[0018] In embodiments of the invention, step (a) comprises advancing the media a nominal distance and step (b) comprises determining the error in the advance of the media with respect to said nominal distance.

[0019] Advantageously, the dot forming elements of said array are arranged a least along a direction of advance of the media, and said subset of dot forming elements excludes elements at least at one end of said array.

[0020] The nominal distance may be determined after each swath, depending on the error found in the previous advance of the media, in such a way that said error is at least partly compensated. The build-up of errors in successive swaths is thus avoided, and the same degree of correction in available in each swath.

[0021] In other embodiments, said error in the position of the media is an error in a direction at right angles to a direction of advance of the media.

[0022] In an embodiment, for all the swaths said subset of dot forming elements comprises the same predetermined number of elements; this avoids the need for more complex printing masks and data processing.

[0023] When all the subsets comprise the same number of elements, preferably the method comprises the step of determining, prior to the first printing swath, a number of dot forming elements for said subset.

[0024] Preferably, said step of determining the error in the position of the media comprises tracking media features at microscopic level by optical means.

[0025] Alternatively, said step of determining the error in the position of the media is carried out by means of a friction wheel in contact with the media.

[0026] In embodiments of the invention the printhead comprises an array of dot forming elements having a density between 600 and 2400 dpi and the subsets of dot forming elements selected for each swath exclude less than 20 dot forming elements, more preferably between between 2 and 10 dot forming elements.

[0027] Advantageously, said at least one printhead performs a reciprocating movement in a scan direction at right angles to the media advance direction.

[0028] In other embodiments, said at least one printhead is a full-width array printhead.

[0029] Preferably, said at least one printhead is an inkjet printhead and said dot forming elements are inkjet nozzles.

[0030] Advantageously, said printhead performs a single-pass printing operation; alternatively, it may perform a multi-pass printing operation.

[0031] According to another aspect, the present invention provides an incremental printing apparatus for printing on a media in a plurality of swaths, comprising means for advancing the media to a nominal position before each swath and at least one printhead provided with an array of ink dot forming elements to print each swath, said apparatus further comprising: means for determining, before at least some swaths, an error between said nominal position of the media and an actual position; means for selecting a subset of said array of dot forming elements depending on said determined error; and means for printing the next swath using dot forming elements of said selected subset.

[0032] Preferably, said at least one printhead is an inkjet printhead and said dot forming elements are inkjet nozzles.

[0033] A particular embodiment of the present invention will be described in the following, only by way of nonlimiting example, with reference to the appended drawings, in which:

- figures 1a, 1b, 1c show schematically a printhead printing on media to illustrate the appearance of banding in single-pass printing mode;
- figures 2a, 2b, 2c show schematically a printhead performing an embodiment of the method of the present invention, in single-pass printing mode;
- figure 3 is a perspective view of the nozzle arrangement of an inkjet printhead;
- figure 4 illustrates steps of a method for single-pass printing according to an embodiment of the invention, that uses the printhead of figure 3; and
- figures 5a, 5b illustrate an embodiment of the invention in multi-pass printing mode.

[0034] In order to aid the understanding of embodiments of the invention, some general aspects will be explained in the following.

[0035] Embodiments of the present invention seek to provide a printing method in which the defects due to errors in the media advance are reduced, without using mechanical adjustment of the position of the media or the printhead.

[0036] This is based on the idea of using only a subset of the nozzles of the printhead for printing each swath, excluding a number of nozzles at least at one end of the printhead; by changing the subset from swath to swath, shifting towards one end of the array or the other the position of the nozzles used for printing, it is possible to compensate errors in the advance of the media.

[0037] In other words, most of the nozzles of the array, namely those that are not near the ends of the array, will belong to all the subsets and will be used in all the swaths, and a small proportion of the nozzles, near the ends of the array, will only belong to some subsets and therefore will only be used in some swaths. These nozzles that are included in the printing subset only in some swaths may be referred to as adjustment or correction nozzles.

[0038] Reference is now made to figures 1a, 1b and 1c, which illustrate schematically the appearance of banding associated with media advance errors in an incremental printing apparatus, e.g. an inkjet printer, in single-pass printing mode.

[0039] The figures depict a web or sheet of printing media 1 on which an inkjet printhead 2 prints an image in swaths. The media advances in a media advance direction Y, while the printhead has a reciprocating motion in a scan direction X at right angles to the media advance direction Y.

[0040] The printhead 2 is provided with an array of inkjet nozzles 3; the nozzles are arranged at least partly aligned along the media advance direction Y, several arrangements being possible.

[0041] In each swath the nozzles of the printhead 2 deposit ink dots on the media forming a strip with a predetermined pattern, while the media remains stationary; the swath height H, i.e. the dimension of the strip in the Y direction, corresponds to the dimension of the array of nozzles. The media is advanced between swaths a distance corresponding to the swath height H.

[0042] If there is no error in the advance of the media between two swaths, the edges of the printed strips 4, 4',4",... will match accurately, as shown in figure 1a.

[0043] However, due to mechanical tolerances in the driving system or to media slippage, the advance of the media may be smaller or larger than the swath height H to an extent that creates a visible artifact in the printed image. The effect of the media advance errors is shown in figure 1b for a swath in which the media has overadvanced, thus leaving a white streak 5, and in figure 1c for a swath in which the media has underadvanced, causing overlapping of two strips 4' and 4" and therefore a dark region 6.

[0044] For example, in an inkjet plotter the errors in the advance of the media may be as large as 100 μm.

[0045] It has to be pointed out that the real proportions of the media, the printhead, the nozzles and the advance errors have not been respected in the appended figures, in order to provide a clear representation.

[0046] In embodiments of the present invention, banding due to media advance errors is reduced in a simple manner by using in each swath only a subset of the array of nozzles 3, the subset excluding some nozzles at least at one end of the array.

[0047] This concept is explained in figures 2a, 2b and 2c, that show schematically a printhead 2 with n nozzles, which are numbered #1,#2,....#n in the figures, aligned along the Y axis: a first swath (figure 2a) is printed with a subset So of the nozzles, excluding two nozzles at each end of the array: #1, #2 at one end and #(n-1), #n at the other end. The media is then advanced a nominal distance H_0 corresponding to the swath height H of the subset So .

[0048] The error e in the advance of the media is then measured, as will be explained further on, and compensated in the next swath by:

- printing the next swath with a nozzle subset S_{+1} or S_{+2} (figure 2b) in case of slight or more severe overadvance of the media, respectively; or
- printing the next swath with a subset S_{-1} or S_{-2} (figure 2c) in case of slight or severe underadvance of the media, respectively.

[0049] In figures 2b and 2c, the boundaries of strip 4' as actually printed with the described method are shown in solid lines, while the boundaries of a strip 4' that would have been printed without the compensation are shown in dotted lines.

[0050] The method allows a substantial reduction of the positioning error between the edges of consecutive strips 4, 4', thus reducing the risk of visible artifacts, and it avoids the accumulation of errors from swath to swath.

[0051] In practice, an ASIC (application-specific integrated circuit) calculates and controls the subsets of nozzles that need to be used for printing, depending on the measured error.

[0052] The compensating ability of the system will depend in each case from the number of nozzles that are excluded from each subset, and from the distance between nozzles, the latter representing the resolution, i. e. the maximum possible accuracy, as will be explained in the following with reference to a specific example.

[0053] Figure 3 shows the nozzle arrangement for one particular inkjet printhead: it comprises four dies 10, each comprising two slots 11; in each slot there are two columns 12 of nozzles 3. In the printing position the dies, slots and columns are arranged along the media advance direction Y.

[0054] Each column 12 has a density of 600 dpi (dots per inch, i.e. nozzles per inch), which means there is a distance d_1 = 42 μm between two adjacent nozzles of the same column.

[0055] As shown in the blown-up portion of the figure, the nozzles are arranged staggered from column to column, and those of each slot with respect to those of the other slot, such that the smallest distance in the media advance direction Y between two adjacent nozzles of one slot is d_2 = 21 μm and the smallest distance between two adjacent nozzles of one die is d_3 = 10.5 μm. The dimension of the dies is such that the printhead has an overall number of 8448 nozzles. This overall number and the overlapping regions between dies are not relevant to the present invention and will not be discussed further.

[0056] With the described structure, the maximum possible density of the ink dots deposited by the printhead, and thus the highest printing quality, is given by nozzles spaced 10.5 μm, which results in a density of 2400 dpi.

[0057] If in this printhead eight nozzles are excluded from each subset used for printing, the maximum possible media advance correction will be of ± 42 μm (four nozzles at each end, spaced 10.5 μm), and the resolution will be of 10.5 μm.

[0058] The loss of swath height due to the exclusion of some nozzles is very small (a proportion of 8/8448, thus less than 0.01% in the case of this specific printhead) and does not jeopardise the printing speed.

[0059] The way the compensation is carried out will be now described with reference to the example of figure 4.

[0060] If the media advance after the first swath, printed with a subset So excluding four nozzles on each side, has an error of e_1 = 36 μm (overadvance), the subset to be used in the next printing swath will need to be displaced three nozzles towards one side with respect to subset S_0 (and therefore the indicated subset S_{+3} would be used), thus compensating 10.5 * 3 = 31.5 μm of the advance error. The remaining error is only: e_2 = 36 μm

- 31.5 µm = 4.5 µm.

[0061] The previous paragraph deals in principle with the case in which the printhead is printing at 2400 dpi. When printing is performed at 1200 dpi or at 600 dpi, two or four nozzles are grouped together; however, the subset of nozzles to be used in each swath can still be selected by excluding the optimum number of nozzles at each end of the printhead, while the grouping of nozzles for 1200 dpi or 600 dpi printing will depend on the selected nozzle subset.

[0062] For example, if at 600 dpi the advance error is 36 µm, the selected subset will be S_{+3} like before, and the grouping of nozzles will start at the second nozzle.

[0063] In a printhead having lower nozzle density, e. g. a printhead having nozzles spaced at 1200 dpi or at 600 dpi, the possibility of compensating media advance errors will be smaller, but will still afford an advantage, e.g. it will reduce at least the largest white streaks and overlaps.

[0064] Obviously the die, slot and nozzle structure described in the example is not limiting: a printhead used in the method according to the invention could have any other layout, as long as it comprises an array of discrete dot forming elements.

[0065] In the above example, the main steps involved in each swath of the printing operation would be as follows:

(a) advance the media a nominal distance, similar to the swath height H_0;
(b) determining the error in the advance of the media;
(c) calculating the number of nozzles corresponding to said error, and selecting a subset of nozzles accordingly; and
(d) printing the next swath using the selected subset of nozzles.

[0066] The nominal distance H_0 that the media has to be advanced between two swaths is not necessarily equal to the swath height H: preferably, it is determined after each swath in order to take into account and compensate at least partly the error found in the previous media advance.

[0067] If in one swath the media has an overadvance of 36 µm as described in the above example, the swath is printed with the corresponding set of nozzles S_{+3} to avoid the appearance of a white streak, and the next nominal advance H_0 is set at H + 36 µm to reconduct the media to a centred position with respect to the printhead.

[0068] This small variation in the nominal distance for media advance in each swath cannot by itself avoid banding, but it avoids the build-up of media positioning errors swath after swath, that could in the end make impossible the compensation of each advance error by the described selection of a subset of nozzles.

[0069] By varying as described the nominal distance that the media has to advance, the same degree of compensation by selecting nozzles subsets is available in each swath.

[0070] The step of determining the error in the advance of the media may be carried out by several means. The detectors are known per se and known to the skilled man, and therefore they have not been described in detail or shown in the figures.

[0071] One possibility is using optical means, such as an image sensor tracking the media fibres or other media features at microscopic level. Alternatively, the error can be measured mechanically, e.g. by means of a friction wheel in contact with the media. The sensors may be located over or under the media.

[0072] In the above example, where the swath height is the same in all the swaths, i.e. all the subsets have the same number of nozzles, this number is selected before the beginning of the printing operation depending on the image to be printed, the media, etc.

[0073] It would also be possible to vary the number of nozzles from swath to swath.

[0074] The above example refers to single-pass printing mode. It is also possible to apply the method in multipass printing, even though the media positining errors in this case are less critical.

[0075] An example of a multi-pass printing operation will now be described with reference to figures 5a and 5b.

[0076] Figure 5a illustrates by way of example a four-pass printing operation, where A,B,C and D show four consecutive swaths, each having a swath height H. In this case the media is only advanced a distance H_0=H/4 between swaths. As a consequence, there is an overlap of the strips printed in successive swaths, and in each swath the printhead 2 deposits only a fraction of the ink dots of the final plot: the superposition of four consecutive swaths completes the image.

[0077] For example, the central printed strip shown on the media 1 in figure 5a is formed by the superposition of swaths A,B,C and D.

[0078] It is of course possible to set a different number of passes to complete the image, for example eight; in each particular case the media advance between swaths will be an appropriate fraction of the swath height H.

[0079] Figure 5b shows an embodiment of the method of the invention applied to the four-pass printing operation of figure 5a.

[0080] The figure shows on the media 1 a grey area corresponding to the strip printed in swath A. The media is then advanced a nominal distance H_0; if the media overadvances H_0+e (the error e being exaggerated in the drawing), the next swath would be as shown by the arrow B(e) and due to the error it would be displaced from its intended position.

[0081] In this case the resulting white streak wouldn't be clearly visible in the final plot, like in single-pass printing mode, because the next swaths (not shown) would partly cover the streak; however, it is still desirable to correct the error in order to improve the quality of the printed plot.

[0082] Therefore, similarly to the example of figure 2b, a large proportion of the error e in the media advance can be corrected by printing the swath indicated by arrow B e.g. with a subset S+2 of the nozzles 3, which excludes nozzles at the left of the printhead (as seen in the drawing).

[0083] The determination of the media advance error and of the nominal advance to be performed after each swath, in multi-pass printing mode, is similar to what has been described in single-pass printing and will not be discussed further.

[0084] The method according to the invention may be applied to an inkjet printing apparatus but also to any other printing technique in which a printhead prints successive swaths with an array of dot forming elements, on a media that is displaced from swath to swath.

[0085] An analogous compensation method, based on the same concept of selecting different subsets of nozzles depending on the media positioning error, may be used in other circumstances: for example the method may be used to compensate media positioning errors in a direction at right angles to the advance, i.e. lateral positioning errors. This can be implemented also in a printer with a full-width array printhead.

[0086] The lateral position of the media is then determined after each swath, and appropriate compensation is implemented in order to avoid an error with respect to a nominal position, which would cause a displacement between printed strips in the direction of the scan axis, which could also cause visible artifacts.

[0087] It is pointed out that a method according to the present invention can be combined with other techniques; for exemple, it could be used in combination with a method for compensating aiming errors or swath height errors of printheads, as described in EP1197916A2 cited above.

Claims

1. A method for printing on media (1), comprising performing a plurality of printing swaths with at least one printhead (2), maintaining the media (1) stationary while printing each swath and advancing the media (1) between swaths, said printhead being provided with an array of dot forming elements (3), wherein after at least some of the swaths said method comprises the steps of:

   (a) advancing the media (1) to a nominal position;
   (b) determining the error in the position of the media with respect to said nominal position;
   (c) depending on said error, selecting a subset (S_0, S_{+1}, S_{-1}, S_{+2}, S_{-2}, S_{+3}, ...) of said array of dot forming elements (3); and
   (d) printing the next swath using dot forming elements (3) from said selected subset (S_0, S_{+1}, S_{-1}, S_{+2}, S_{-2}, S_{+3}, ...).

2. A method as claimed in claim 1, wherein step (a) comprises advancing the media a nominal distance (H_0) and step (b) comprises determining the error in the advance of the media with respect to said nominal distance (H_0).

3. A method as claimed in claims 1 or 2, wherein the dot forming elements of said array are arranged a least along a direction (Y) of advance of the media (1), and wherein said subset (S_0, S_{+1}, S_{-1}, S_{+2}, S_{-2}, S_{+3}, ...) of dot forming elements excludes elements (3) at least at one end of said array.

4. A method as claimed in claims 2 or 3, wherein said nominal distance (H_0) is determined after each swath, depending on the error found in the previous advance of the media, in such a way that said error is at least partly compensated.

5. A method as claimed in claim 1, wherein said error in the position of the media (1) is an error in a direction (X) at right angles to a direction (Y) of advance of the media (1).

6. A method as claimed in any of the previous claims, wherein for all the swaths said subset (S_0, S_{+1}, S_{-1}, S_{+2}, S_{-2}, S_{+3}, ...) of dot forming elements comprises the same predetermined number of elements (3).

7. A method as claimed in claim 6, comprising the step of determining, prior to the first printing swath, a number of dot forming elements (3) for said subset (S_0, S_{+1}, S_{-1}, S_{+2}, S_{-2}, S_{+3}, ...).

8. A method as claimed in any of claims 1 to 7, wherein said step of determining the error in the position of the media (1) comprises tracking media features at microscopic level by optical means.

9. A method as claimed in any of claims 1 to 7, wherein said step of determining the error in the position of the media (1) is carried out by means of a friction wheel in contact with the media (1).

10. A method as claimed in any of the previous claims, wherein the printhead (2) comprises an array of dot forming elements (3) having a density between 600 and 2400 dpi and the subsets (S_0, S_{+1}, S_{-1}, S_{+2}, S_{-2}, S_{+3}, ...) of dot forming elements (3) selected for each swath exclude less than 20 dot forming elements (3).

11. A method as claimed in claim 10, wherein the sub-

set (S_0, S_{+1}, S_{-1}, S_{+2}, S_{-2}, S_{+3}, ...) of dot forming elements (3) selected for each swath excludes between 2 and 10 dot forming elements (3).

12. A method as claimed in any of claims 1 to 11, wherein said at least one printhead (2) performs a reciprocating movement in a scan direction (X) at right angles to the media advance direction (Y).

13. A method as claimed in any of claims 1 to 11, wherein said at least one printhead (2) is a full-width array printhead.

14. A method as claimed in any of the previous claims, wherein said at least one printhead is an inkjet printhead (2) and said dot forming elements (3) are inkjet nozzles (2) .

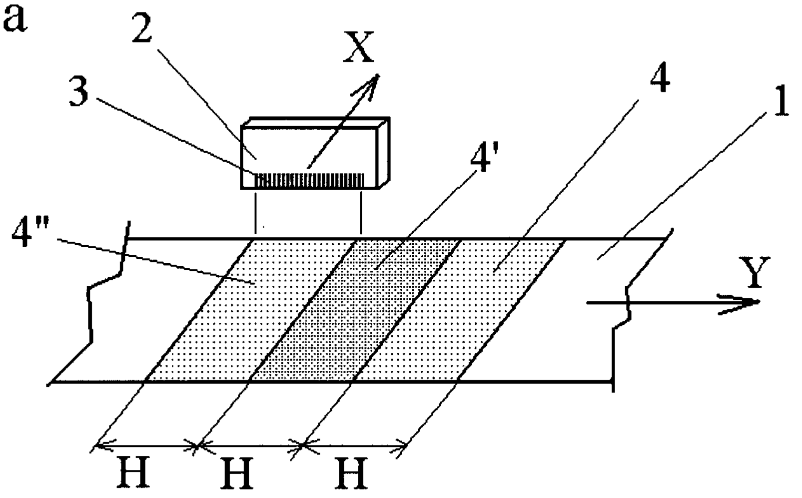
15. A method as claimed in any of claims 1 to 14, wherein said printhead performs a single-pass printing operation.

16. A method as claimed in any of claims 1 to 14, wherein said printhead performs a multi-pass printing operation.

17. An incremental printing apparatus for printing on a media (1) in a plurality of swaths, comprising means for advancing the media (1) to a nominal position before each swath and at least one printhead (2) provided with an array of ink dot forming elements (3) to print each swath, said apparatus further comprising: means for determining, before at least some swaths, an error between said nominal position of the media and an actual position; means for selecting a subset (S_0, S_{+1}, S_{-1}, S_{+2}, S_{-2}, S_{+3}, ...) of said array of dot forming elements (3) depending on said determined error; and means for printing the next swath using dot forming elements (3) of said selected subset (S_0, S_{+1}, S_{-1}, S_{+2}, S_{-2}, S_{+3}, ...).

18. An apparatus as claimed in claim 17, wherein said at least one printhead is an inkjet printhead (2) and said dot forming elements are inkjet nozzles (3).

FIG. 1a



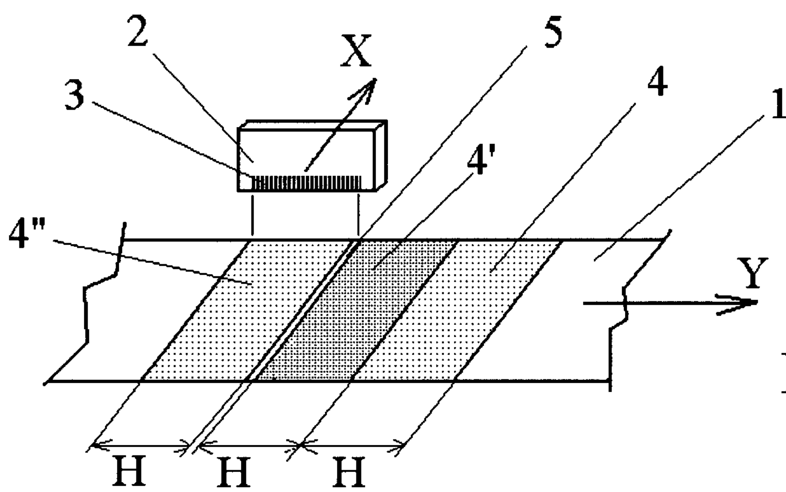


FIG. 1b

FIG. 1c

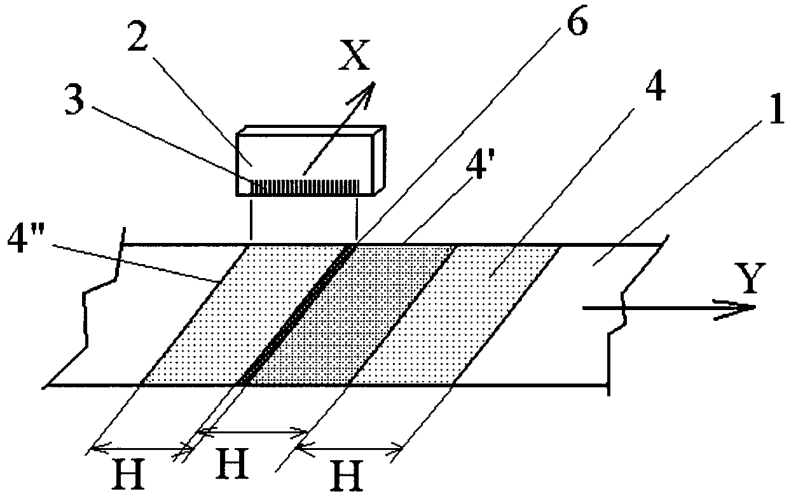


FIG. 2a

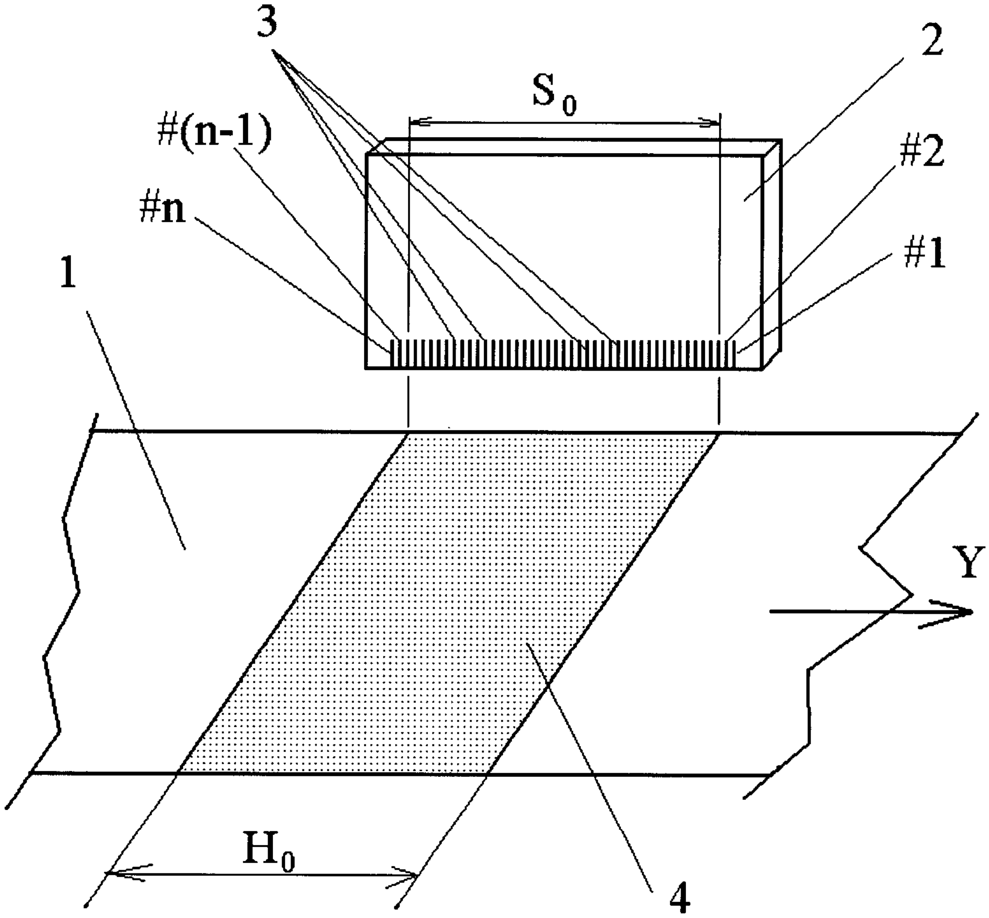


FIG. 2b

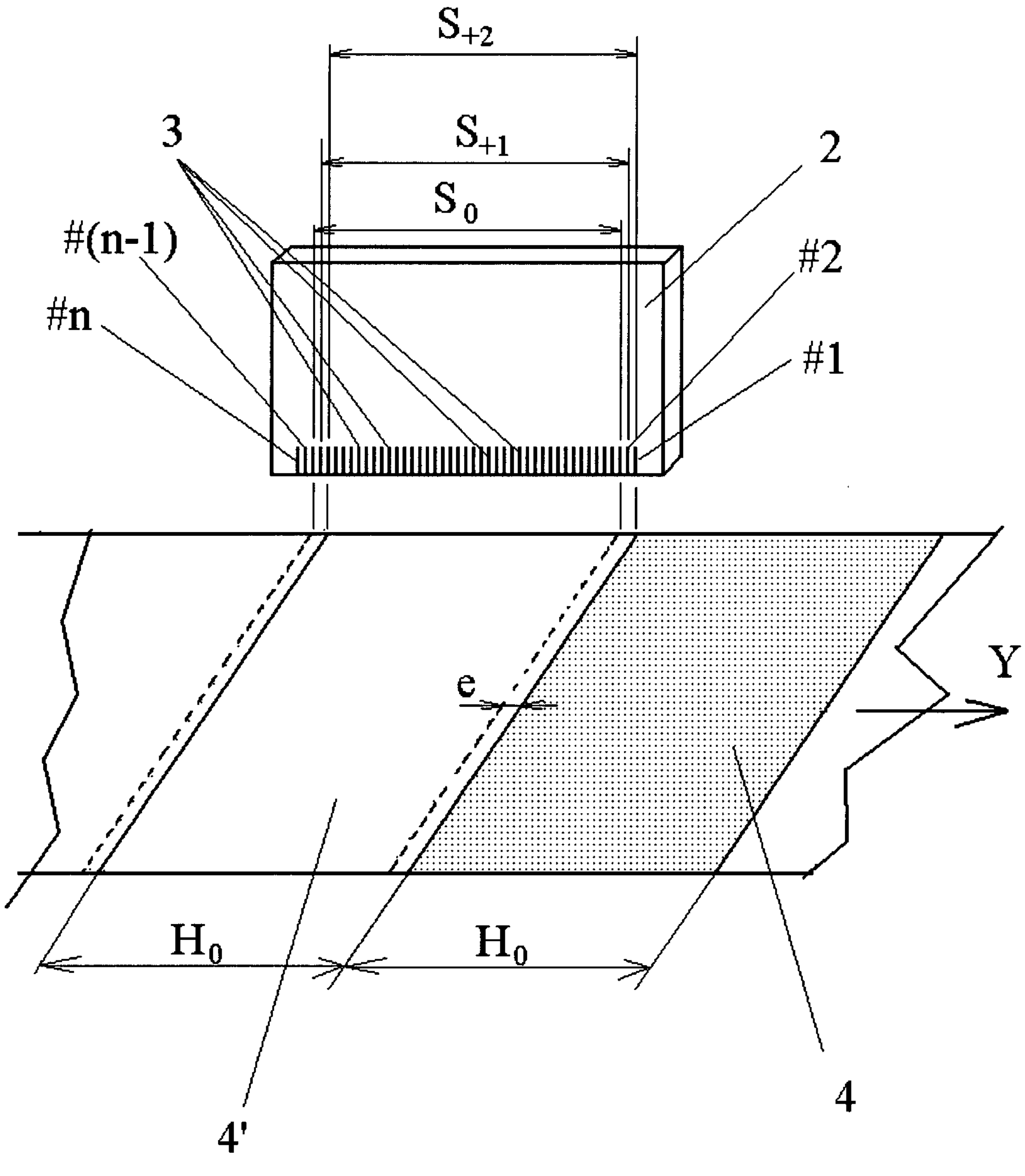


FIG. 2c

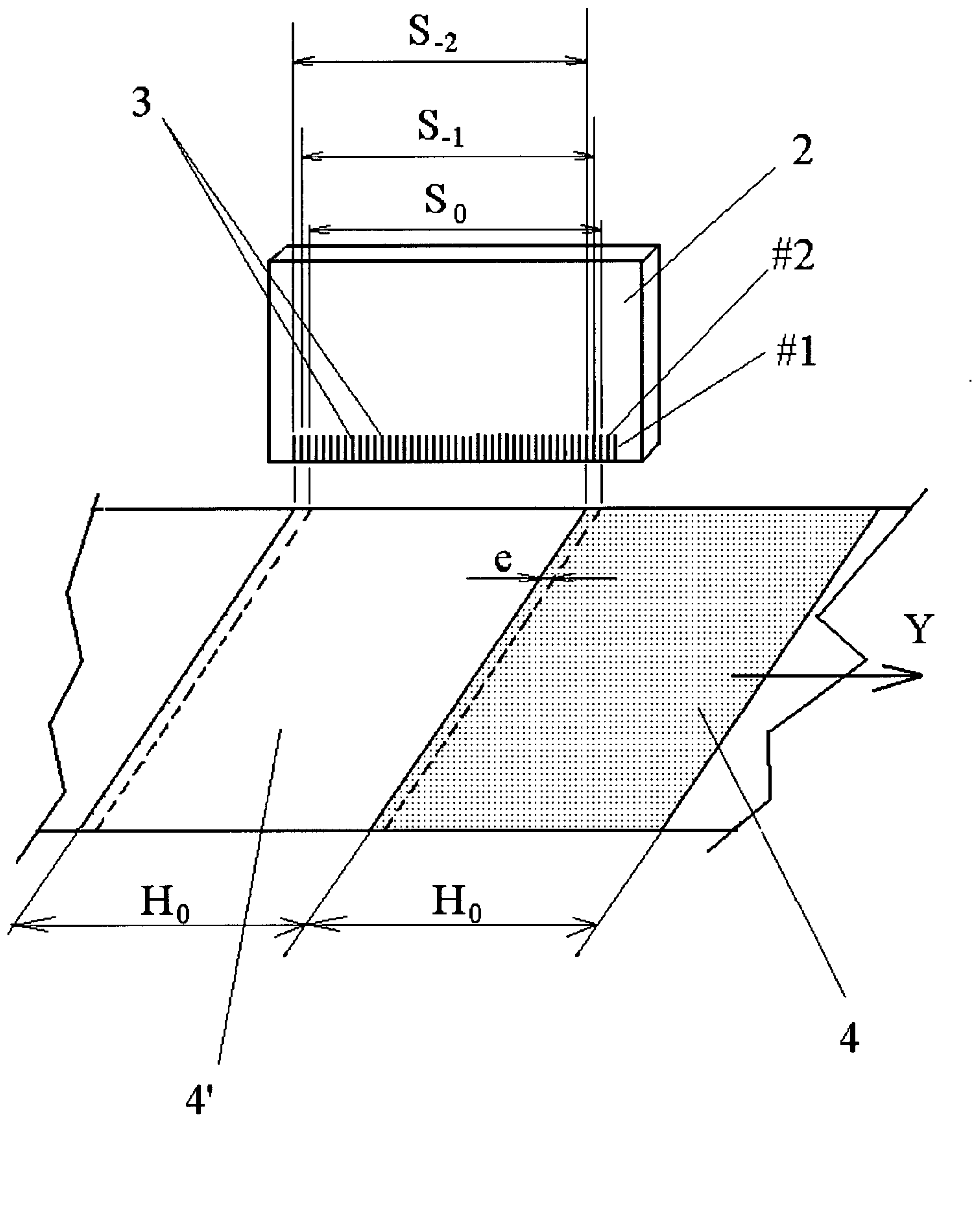


FIG. 3

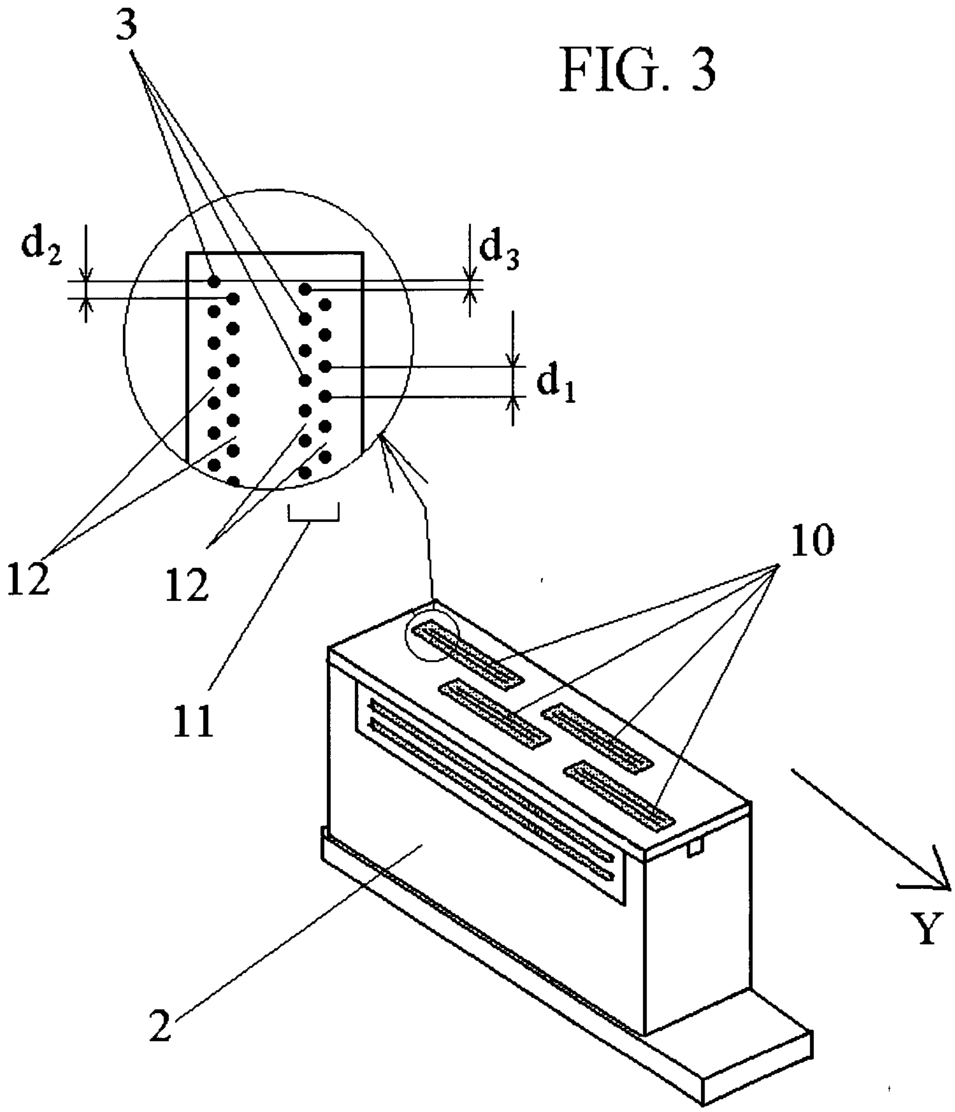


FIG. 4

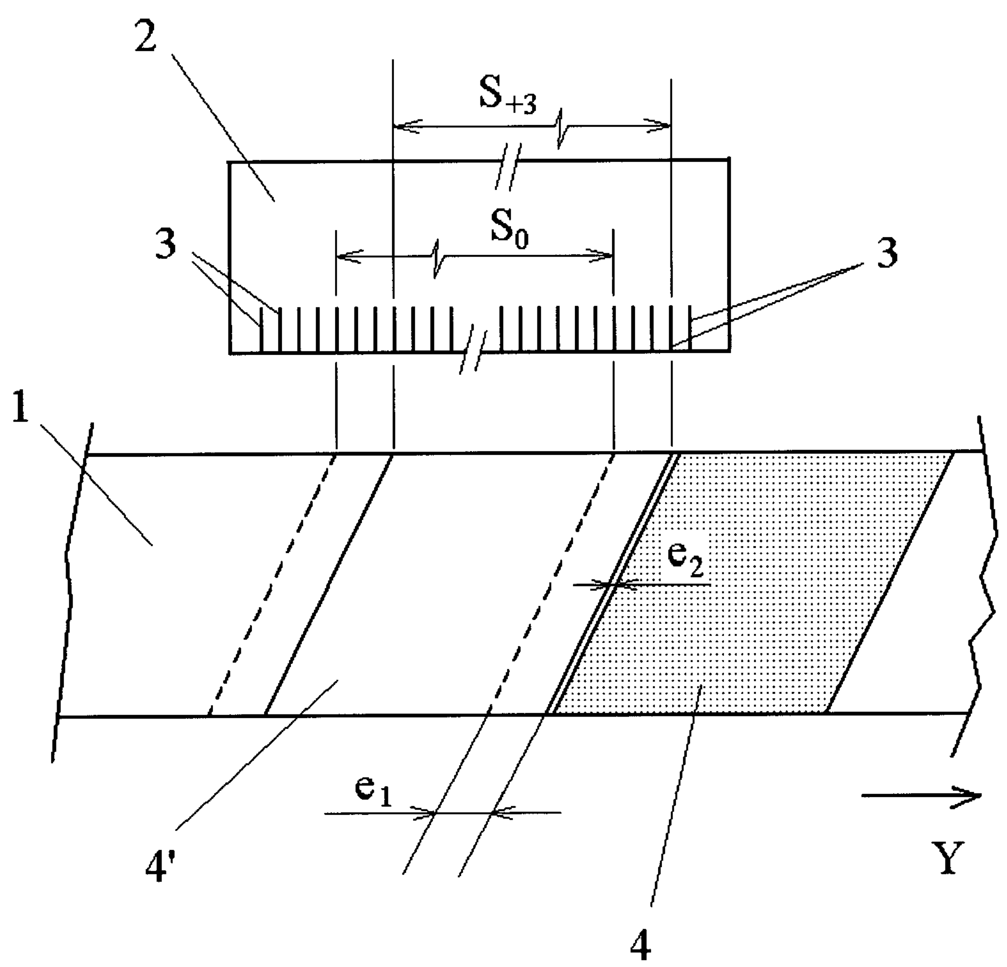


FIG. 5a

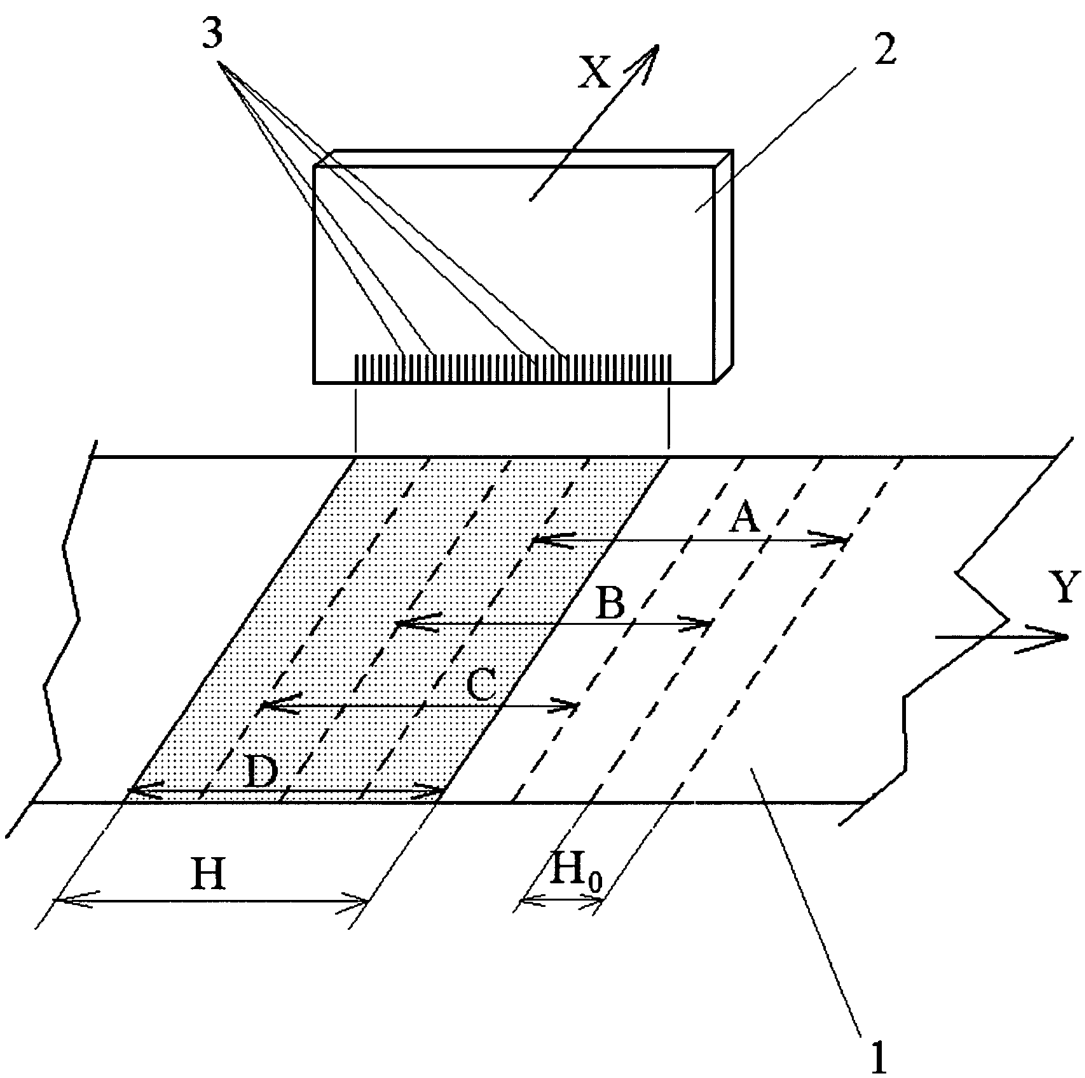
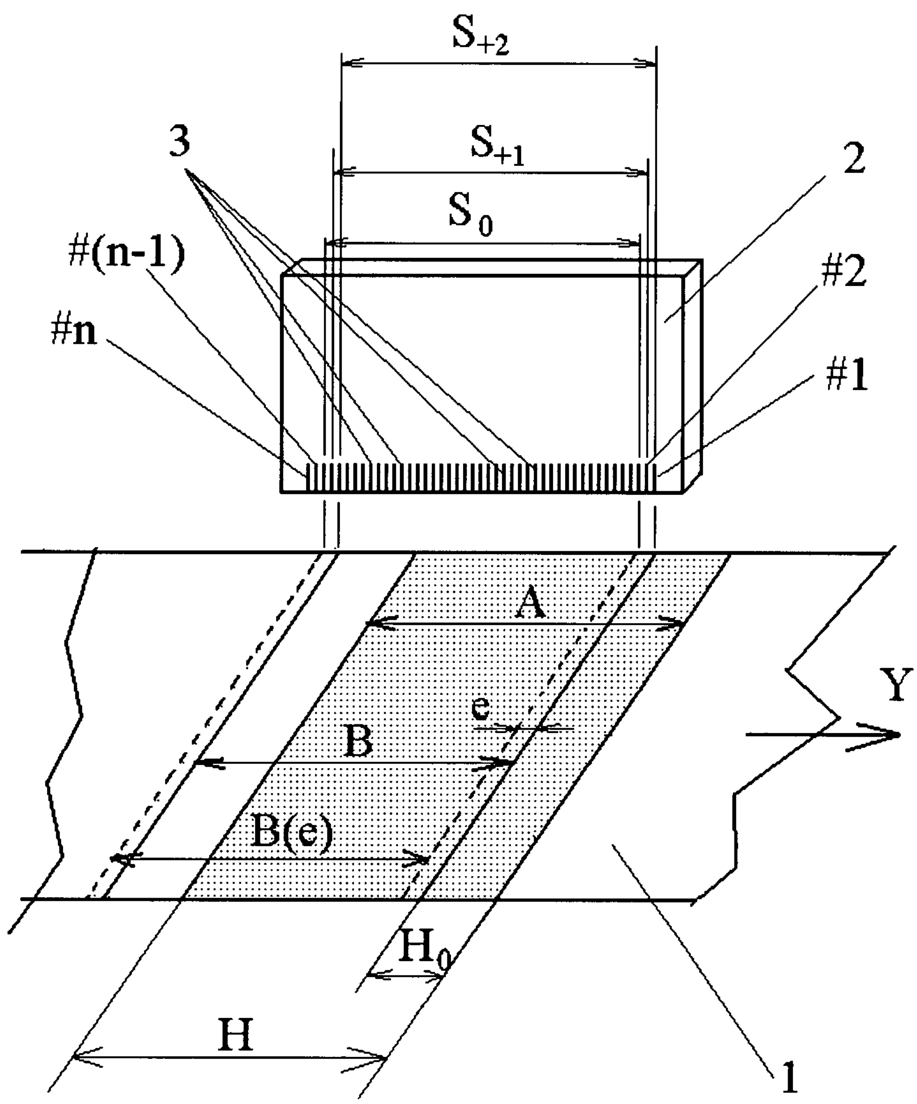


FIG. 5b



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EUROPEAN SEARCH REPORT

Application Number
EP 02 02 3286

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	25 March 2003	Zacchini, D

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