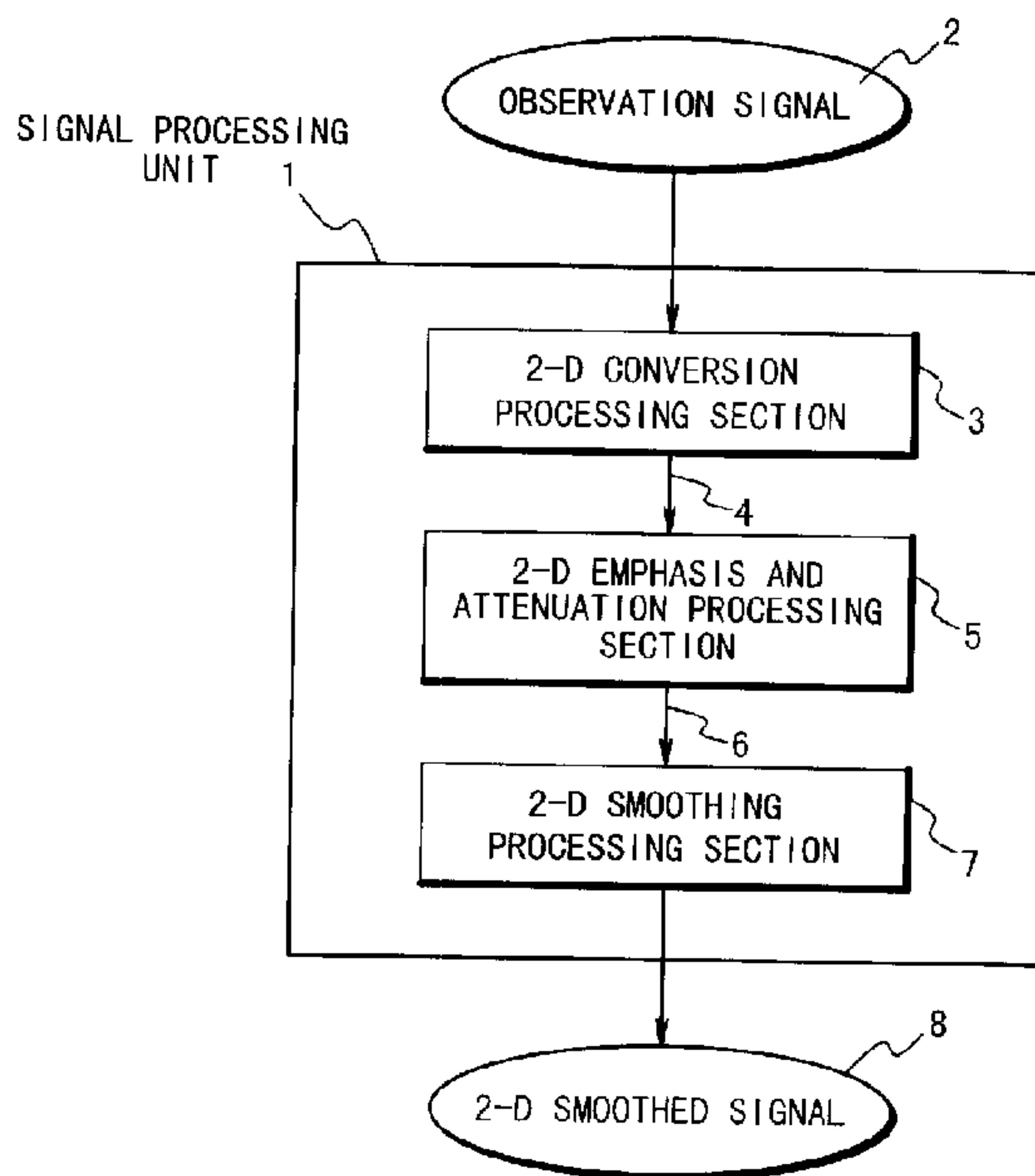




(22) Date de dépôt/Filing Date: 1999/08/03
 (41) Mise à la disp. pub./Open to Public Insp.: 2000/02/05
 (45) Date de délivrance/Issue Date: 2003/05/20
 (30) Priorité/Priority: 1998/08/05 (233627/1998) JP

(51) Cl.Int.⁶/Int.Cl.⁶ G01D 3/032, G01N 27/90, G06T 1/00
 (72) Inventeurs/Inventors:
 KAWATA, KAYOKO, JP;
 KUMANO, SHINTARO, JP;
 MATSUMOTO, MITSUYOSHI, JP
 (73) Propriétaire/Owner:
 MITSUBISHI HEAVY INDUSTRIES, LTD., JP
 (74) Agent: G. RONALD BELL & ASSOCIATES

(54) Titre : DISPOSITIF DE TRAITEMENT DE SIGNAL
 (54) Title: SIGNAL PROCESSING APPARATUS



(57) Abrégé/Abstract:

A signal processing apparatus according to the present invention includes a 2-dimensional conversion processing section, a 2-dimensional emphasis and attenuation processing section and a 2-dimensional smoothing processing section. The 2-dimensional conversion processing section maps an observation signal in a first coordinate system onto a second coordinate system to output a 2-dimensional converted signal. The observation signal includes a detection object component and a noise component to be attenuated, the noise component being composed of a first noise component and a second noise component. The 2-dimensional emphasis and attenuation processing section attenuates the first noise component to emphasize the detection object component and outputs a 2-dimensional filtered signal in which the detection object component is emphasized. The 2-dimensional smoothing processing section attenuates the second noise component contained in the 2-dimensional filtered signal, and outputs a 2-dimensional smoothing signal, whereby a detection object can be detected based on the 2-dimensional smoothed signal.

ABSTRACT

A signal processing apparatus according to the present invention includes a 2-dimensional conversion processing section, a 2-dimensional emphasis and attenuation processing section and a 2-dimensional smoothing processing section. The 2-dimensional conversion processing section maps an observation signal in a first coordinate system onto a second coordinate system to output a 2-dimensional converted signal. The observation signal includes a detection object component and a noise component to be attenuated, the noise component being composed of a first noise component and a second noise component. The 2-dimensional emphasis and attenuation processing section attenuates the first noise component to emphasize the detection object component and outputs a 2-dimensional filtered signal in which the detection object component is emphasized. The 2-dimensional smoothing processing section attenuates the second noise component contained in the 2-dimensional filtered signal, and outputs a 2-dimensional smoothing signal, whereby a detection object can be detected based on the 2-dimensional smoothed signal.

- 1 -

SIGNAL PROCESSING APPARATUS

Background of the Invention

1. Field of the Invention

5 The present invention relates to a signal processing apparatus, and more particularly to a signal processing apparatus in which a difference between a signal component and a noise component in a spatial frequency component is utilized for noise reduction.

10

2. Description of the Related Art

 Pipes with various diameters are used in a large-scale plant such as an atomic generation plant and a thermal power generation plant. Such pipes are subject to influences such as vibration and heat change, and a flaw or damage sometimes occurs inside the pipe as a result of these influences. In order to ensure the safety of the operation of the large-scale plant, the pipes should be tested to see whether any flaw or damage has occurred. A non-destructive test is usually performed.

20

 There are various conventional non-destructive test methods. Known non-destructive tests include a supersonic flaw detecting method and an eddy current testing method.

 In the eddy current test (ECT) method, a small flaw can be detected, but the results can be easily influenced by noise. A sensor used in the eddy current test is generally a rotary type sensor, which is rotated into a circumferential direction in a test body such as a pipe while progressing into

25

- 2 -

an axial direction thereof. Eddy current is generated in a metal body of the test body by a moving magnetic field generating body or a stationary magnetic force changing coil. The magnetic force generated by the eddy current is measured
5 as a function of a position coordinate.

A noise component comprises a support structure noise component, a pipe diameter change noise component, an adhesion noise component, a sensor fluctuation noise component and an electric noise component. Techniques such as (1) a band pass
10 filtering method, (2) a multiple frequency calculating method and (3) a line filtering method are generally applied as conventional methods to remove such noise components.

In the band pass filtering method, a signal is observed from the test body such as a pipe as a time series
15 signal, and a component of the signal other than a specific frequency band is attenuated. This band pass filtering method will be described with reference to Figure 1. First, in order to analyse in a frequency region, an observation signal $x(n)$ as the time series signal is subjected to a conversion
20 (Fourier transform) from a time domain into a frequency domain so that a frequency spectrum $X(f)$ is obtained. The observation signal $X(n)$ comprises a noise component and a damage component as a detection object component, which indicates the existence and shape of a damage in the test
25 body.

Next, a weighting operation is performed to the frequency spectrum $X(f)$ by use of a band pass window having the frequency response of $w(f)$ to obtain a frequency spectrum

- 3 -

$X'(f)$. The weighting operation attenuates any frequency component outside a specific frequency region. In order to obtain a band pass signal $X'(n)$ after the filtering, an inverse Fourier transform is performed to the band pass signal $X'(f)$ so that a band pass signal $X'(n)$ is obtained as a time series signal in which any frequency component outside the specific frequency band is attenuated.

Next, referring to Figure 2, a multiple frequency calculating method is illustrated. In this method, the way of changing a detected signal is different, depending on a signal generation factor, when an excitation frequency is different. In the multiple frequency calculating method, a linear calculation of a multiple frequency signal ($X_1(t)$, $X_2(t)$, $X_3(t)$ and $X_4(t)$) is performed using filtering parameters (W_1 , W_2 , W_3 and W_4) previously set to output a synthetic signal $Y(t)$ in which only a damage component as a detection object component remains.

Figures 3A and 3B show a line filtering method. In this method, a component for one line, which specified as a reference line, is removed from a 2-dimensionally distributed original signal.

In the above-mentioned band pass filtering method, the frequency spectrum of the observed time series signal is analysed by considering a 1-dimensional component of a 2-dimensionally distributed signal. Therefore, the detected frequency response is easily altered depending upon the directions of the detection object component and noise component.

- 4 -

Another problem is that the signal obtained after the filtering operation appears similar to a vibration. Therefore, the position precision is degraded when a narrowing of the band width of the filter is attempted.

5 The multiple frequency calculating method is effective when the phase angles of the detection object component and noise component are clearly different. However, when the phase angles are close to each other, the filtering effect is low. For example, phase angles are close to each other when
10 there is a damage signal and a deformation signal on the surface of the test body on side of the sensor.

Moreover, the line filtering method has the effect of reducing a uniformly distributed noise component in a 1-dimensional direction of the 2-dimensionally distributed
15 signal. However, the reduction is minimized when there is a noise component other than the uniformly distributed noise component in the 1-dimensional direction. Also, even if the noise component is uniformly distributed in the 1-dimensional direction, an unnecessary component remains when the
20 uniformity is not broken due to the drift or another cause. Moreover, the reference line which is central to the line filtering method should be estimated based on the observation signal. Therefore, there is a risk of attenuating the detection object component when an error occurs in the
25 estimation.

In the eddy current testing method, the properties of the damage such as direction, length, width and depth have various values. However, because a detection signal is

- 5 -

obtained by observing the change of the eddy current flowing through the test body, the frequency components of the detection signal are spread 2-dimensionally in accordance with the excitation frequency, even if the damage is small.

5 On the other hand, the noise component is different from the damage component as a detection object component in a 2-dimensional spatial frequency spectrum. The noise component comprises the pipe support structure noise component, the pipe diameter change noise component, the
10 adhesion noise component and the sensor fluctuation noise component. The noise component has a low frequency component in at least one of the 2 dimensions, in contrast to the spatial frequency spectrum of the damage component. On the other hand, the electric noise component has a frequency
15 component higher than the spatial frequency spectrum of the damage component.

Summary of the Invention

 An object of the present invention is to provide a signal processing apparatus which has a highly precise
20 detection ability, and in which the filtering technique is used based on the difference between a detection object component and a noise component to be attenuated in a spatial frequency spectrum.

 In order to achieve an aspect of the present
25 invention, a signal processing apparatus for reducing noise is provided comprising a 2-dimensional conversion processing section which maps an observation signal in a first coordinate system into a second orthogonal coordinate system to output

- 6 -

a 2-dimensional converted signal, wherein said observation signal includes a detection object component and a noise component to be attenuated, and said noise component is composed of a first noise component and a second noise component; a 2-dimensional emphasis and attenuation processing section which attenuates said first noise component of said 2-dimensional converted signal to emphasize said detection object component thereof and outputs a 2-dimensional filtered signal in which said detection object component is emphasized; and a 2-dimensional smoothing processing section which attenuates said second noise component contained in said 2-dimensional filtered signal, and outputs a 2-dimensional smoothed signal, whereby a detection object can be detected based on said 2-dimensional smoothed signal and based on a difference between the detection object component to be detected and the noise component to be attenuated in a spatial frequency spectrum.

The 2-dimensional emphasis and attenuation processing section may include a 2-dimensional digital differential filter. Also, the 2-dimensional smoothing processing section may include a median filter.

For reference purposes, it is noted that copending divisional application No.2,339,321 describes and claims a non-destructive testing apparatus which includes a detector, a display unit and a processor. The detector measures a test object to generate a measurement signal in a first coordinate system. The processor maps the measurement signal in the first coordinate system onto a second coordinate system to

- 7 -

produce a second coordinate system measurement signal, removes a noise component from the second coordinate system measurement signal to produce a resultant signal, and controls the display unit to display the resultant signal.

5 The detector may be a rotary type detector, and the first coordinate system may be a polar coordinate system. Alternatively, the detector may be a multi-coil type sensor, and the first coordinate system may be a 2-dimensional coordinate system.

10 Also, the second coordinate system may be a 2-dimensional orthogonal coordinate system. In this case, the processor converts each of the values of the measurement signal to an approximate value on the 2-dimensional orthogonal coordinate system, while mapping the measurement signal in the
15 first coordinate system onto the 2-dimensional orthogonal coordinate system.

 Also, the processor may attenuate a part of the noise component from the second coordinate system measurement signal. In this case, the processor may attenuate the part
20 of the noise component from the second coordinate system measurement signal using a filter of a first frequency cutting type. Moreover, the filter may be a 2-dimensional digital differential filter.

 Also, the processor may remove the remaining part of
25 the noise component from the second coordinate system measurement signal. In this case, the processor may smooth the second coordinate system measuring signal to remove the remaining part of the noise component from the second

- 8 -

coordinate system measurement signal. Moreover, the processor may smooth the second coordinate system measuring signal using a filter to remove the remaining part of the noise component from the second coordinate system measurement signal. The
5 filter may be a median filter.

The divisional application also describes a non-destructive testing method of a test object which includes: measuring a test object to generate a measurement signal in a first coordinate system; mapping the measurement signal in
10 the first coordinate system onto a second coordinate system to produce a second coordinate system measurement signal; removing a noise component from the second coordinate system measurement signal to produce a resultant signal; and providing information of the test object based on the
15 resultant signal.

In addition, another aspect of the divisional application relates to a non-destructive testing apparatus which includes: a detector for measuring a test object to generate a measurement signal in a first coordinate system;
20 a display unit; and a first filter for attenuating a first frequency region of an input signal to produce a first filtering resultant signal; a second filter for attenuating a second frequency region of an input signal to produce a second filtering resultant signal, the second frequency region
25 being apart from the first frequency region; and a processor for: executing mapping of the measurement signal in the first coordinate system onto a second coordinate system adaptable for the first filter; selectively executing mapping of a first

- 9 -

filtering resultant signal in the second coordinate system into a third coordinate system adaptable for the second filter; and

controlling the display unit to display a second
5 filtering resultant signal.

Brief Description of the Drawings

Figure 1 is a diagram illustrating a conventional band pass filtering method;

10 Figure 2 is a diagram illustrating a conventional multiple frequency calculating method;

Figures 3A and 3B illustrate a conventional line filtering method;

15 Figure 4 is a block diagram illustrating a signal processing apparatus of a non-destructive testing apparatus;

Figures 5A to 5C are diagrams illustrating a signal subjected to a mapping process in a rotary sensor;

20 Figures 6A and 6B are diagrams illustrating a signal subjected to the mapping process in a multi-coil type detector;

Figures 7A and 7B are diagrams illustrating a 2-dimensional mapping process;

25 Figure 8 is a diagram illustrating the position where each spectrum component in the spatial frequency region exists;

Figure 9A is a diagram illustrating the 2-dimensional digital differential filtering process, and Figure 9B is a

- 10 -

diagram illustrating an example of a differential type operator;

Figure 10A is a color tone diagram illustrating a mapping result of an observation signal into a plane coordinate system, and Figure 10B shows a three-dimensional view of the mapping result of Figure 10A;

Figure 11A is a color tone diagram showing a processing result by the signal processing apparatus of the present invention, and Figure 11B shows a three-dimensional view of the processing result of Figure 11A;

Figure 12A is a color tone diagram showing a processing result by a conventional band pass filtering method, and Figure 12B shows a three-dimensional view of the processing result of Figure 12A;

Figure 13A is a color tone diagram showing a processing result by a conventional multiple frequency calculating method, and Figure 13B shows a three-dimensional view of the processing result;

Figure 14A is a color tone diagram showing a processing result by a conventional line filtering method, and Figure 14B shows a three-dimensional view of the processing result.

Description of the Preferred Embodiments

A non-destructive testing apparatus which is the subject of the aforementioned divisional application, including a signal processing apparatus of the present

- 11 -

invention will be described in detail with reference to the attached drawings.

Figure 4 shows the structure of a non-destructive testing apparatus which includes a signal processing unit according to an embodiment of the present invention. Referring to Figure 4, the non-destructive testing apparatus includes a detector 2 of a rotary type, a signal processing unit 1 and a display unit 8. The signal processing unit 1 may be a processor. The signal processing unit 1 includes a 2-dimensional conversion processing section 3, a 2-dimensional emphasis and attenuation processing section 5 and a 2-dimensional smoothing processing section 7.

The 2-dimensional conversion processing section 3 will be described below. Referring to Figures 5A to 5C, in an observation signal detected by the detector 2 in an eddy current testing method, sample points are arranged in spiral in correspondence with a test body such as a pipe, as shown in Figure 5B. The 2-dimensional conversion processing section 3 maps the observation signal from a polar coordinate system onto a 2-dimensional orthogonal plane coordinate system. Thus, a 2-dimensional mapped signal is obtained, as shown in Figures 7A and 7B.

The damage component, as a detection object component, and a noise component are contained in the observation signal and the 2-dimensional mapped signal. The noise component is composed of an environment dependent noise component and an electric noise component. The environment dependent noise component comprises a noise component based on a support

- 12 -

structure of a pipe, a noise component based on the change of a pipe diameter, a noise component based on an adhesion and a noise component based on the fluctuation of a sensor.

Figure 8 shows the spectral component positions of the damage component as the detection object component, the environment noise component and the electric noise component in the spatial frequency region. Frequencies f_x and f_y are equivalent to the frequencies in the respective axes of the orthogonal plane coordinate system shown in Figure 7B.

The environment noise component has a spectrum component in the low frequency region in at least one of the 2 dimensions, in contrast to the spatial frequency spectrum component of the damage component. The electric noise component has a spectrum component in the frequency region higher than the spatial frequency spectrum component of the damage component. It should be noted that although the respective components are separated in the figure, the regions overlap each other in reality.

Based on the above, the 2-dimensional emphasis and attenuation processing section 5 attenuates the environment noise component contained in the 2-dimensional mapped signal to output a 2-dimensional filtered signal in which the damage component is emphasized. In this embodiment, a 2-dimensional digital differential filter is used in the 2-dimensional emphasis and attenuation section 5.

Next, the 2-dimensional smoothing processing section 7 attenuates the electric noise component as the high frequency component contained in the 2-dimensional filtered

- 13 -

signal, to output a 2-dimensional smoothed signal. In this embodiment, a median filter is used in the 2-dimensional smoothing processing section 7.

5 Next, the operation processing of the signal processing unit 1 of the present invention will be described in detail.

Referring to Figures 5A to 5C and Figures 6A and 6B, the observation signal detected by the detector 2 in the eddy current testing method will be described first.

10 Figures 5A to 5C and Figures 6A and 6B illustrate a manner in which the sample points may be arranged 2-dimensionally in the eddy current testing method. Figure 5A illustrates a sample signal detected by the rotary type detector 2. Figure 5B illustrates an example of the sample
15 points which are detected spirally in a constant interval in correspondence with the test body. In Figure 5B, the sample points are indicated by black circles because the rotary type sensor is rotated while progressing into an axial direction of the test body.

20 If the observation signal is outputted as a function of time, a 1-dimensional time waveform is obtained, as illustrated in Figure 5A. As illustrated in Figure 5C, the axis direction of the test body, i.e., the direction of the movement of the rotary type detector 2, is set as a horizontal
25 axis, and the circumferential direction is also set as a vertical axis. In this case, the observation or measurement values can be obtained on a circular cylinder coordinate system or a spiral coordinate system. The points on the

- 14 -

circular cylinder coordinate system or the polar coordinate system are converted or mapped onto points on an orthogonal plane coordinate system, and the intensities of the observation signal are shown in an axial direction which is
5 orthogonal to the plane.

Also, Figure 6A illustrates the results obtained by a multi-coil type detector. This detector employs a method of gathering samples in which a plurality of sensors fixed to each other in a given position are moved in the same oblique
10 direction, i.e., a direction not orthogonal to the direction of a row of the plurality of sensors.

The black circles as sample points shown in Figure 6A are not only arranged on a flat plane but also on a circular cylinder plane. By setting the direction of the sensor
15 movement to a horizontal axis and the direction of the sensor arrangement to a vertical axis, the observation values illustrated in Figure 6B may be obtained.

The sample points obtained by the above-mentioned rotary type detector and the multi-coil type detector are not
20 necessarily arranged in the axial direction of the test body. Therefore, it is necessary to map the detection signal in the spiral coordinate system or the polar coordinate system onto the orthogonal plane coordinate system.

The 2-dimensional conversion processing section 2
25 converts the observation values of the observation signal shown in Figure 7A from the rotary type detector or multi-coil type detector into observation values shown in Figure 7B in the orthogonal plane coordinate system while interpolating or

- 15 -

correcting the observation values. That is, the observation values are digitized for the orthogonal plane coordinate system. The interpolating or correcting process is executed during the digitizing process of the mapping process. The 2-dimensional conversion processing section 2 outputs the 2-dimensional mapped signal having interpolated processing values on the coordinate regions as shown in Figure 7B. A symbol ▲ shows a sample point after the mapping process.

In this embodiment, the mapping process is carried out by use of a linear interpolating process. Also, it becomes possible to positively apply a digital filtering technique to be mentioned later, by carrying out the interpolating process.

The 2-dimensional emphasis and attenuation processing section 5 calculates the damage component from the 2-dimensional mapped signal which is arranged in the orthogonal plane coordinate system. Then, the 2-dimensional emphasis and attenuation processing section 5 detects the damage component to output a 2-dimensional filtered signal. In this embodiment, the 2-dimensional digital differential filter is applied to the 2-dimensional emphasis and attenuation processing section 5.

The processing of the 2-dimensional digital differential filter will be described below. In this embodiment, a differential type operator shown in Figure 9B, and similar to the spatial differential operation, is used for calculating the 2-dimensional mapped signal.

Referring to Figure 9A, a convolution calculation is carried out on a signal contained in a local area 9 of the

- 16 -

original signal arranged 2-dimensionally, i.e., the 2-dimensional mapped signal using the differential type operator or a differential pattern. It should be noted that the differential type operator shown in Figure 9B is used in this
5 embodiment. The appropriate differential type operator must be selected depending upon the size of the local area 9 and the direction.

In the convolution calculation processing using the differential type operator shown in Figure 9B, a signal
10 component which is uniformly distributed over the X- and Y-axes in Figure 9A may be attenuated. That is, the signal component in the axial direction and the circumferential direction of the test body can be attenuated. In this way, the environment noise component contained in 2-dimensional
15 mapped signal can be attenuated. The environment noise component exists in a low frequency region in at least one of the X-axis and the Y-axis.

The 2-dimensional smoothing processing section 7 carries out the smoothing process to the 2-dimensional
20 filtered signal and outputs a 2-dimensional smoothed signal. In this embodiment, a median filter is applied to the 2-dimensional smoothing processing section 7.

The median filter outputs a signal value contained in the local area 9 as a signal value in a corresponding local
25 area in the orthogonal plane coordinate system in which a 2-dimensional filtered signal is accommodated.

Through this calculation processing, the intensity (concentration) change becomes gradual between the respective

- 17 -

local areas in the signals which are accommodated on the orthogonal plane coordinate system. This shows that the electric noise component of a high frequency component in the spatial frequency is attenuated.

5 Through the processing of the above signal processing unit 1, the noise component is attenuated in the observation signal and the damage component as a detection object component can be detected. The detected damage component is displayed on the display unit 8 by the signal processing unit
10 1.

It should be noted that the damage component never spreads over {(the width or length of the damage component before the processing) + (the width or length of the operator)}. Therefore, the degradation in the position
15 precision is very low, unlike the conventional band pass filtering method.

A non-destructive testing apparatus used in conjunction with a signal processing unit of the present invention can detect the detection object signal with a high
20 precision. This is because the difference in the spatial frequency spectrum between the damage component to be detected and the noise component to be attenuated, provides a basis for the filtering technique that is used. A comparison of the detection precision in the signal processing unit of the
25 present invention and that of the conventional technology will be described below.

Figures 10A and 10B are diagrams showing a manner in which an observation signal is mapped onto an orthogonal

- 18 -

plane coordinate system by the 2-dimensional conversion processing section 3 of the present invention. Figure 10A shows a color tone diagram, and Figure 10B shows a three-dimensional view of Figure 10A. In the color tone diagram, the horizontal axis represents an axial direction of the test body and the vertical axis represents a circumferential direction. Moreover, a signal value is represented by different shades of color such that a higher brightness (i.e. a lighter color) represents a larger signal value.

Figures 11A and 11B are diagrams showing the processing result by the signal processing section of the present invention. Figure 11A shows a color tone diagram, and Figure 11B shows a three-dimensional view of Figure 11A. It may be understood from these diagrams that the noise component is attenuated and only the damage component is detected clearly.

Figures 12A and 12B are diagrams showing a detection result by the conventional band pass filtering method. Figure 12A shows a color tone diagram, and Figure 12B shows a three-dimensional view of Figure 12A.

Figures 13A and 13B show a detection result by the conventional multiple frequency calculating method. Figure 13A shows a color tone diagram, and Figure 13B shows a three-dimensional view of Figure 13A. Figures 14A and 14B show a detection result by the conventional line filtering. Figure 14A shows a color tone diagram, and Figure 14B shows a three-dimensional view of Figure 14A.

- 19 -

It should be noted that in the color tone diagram, the horizontal axis represents an axial direction of the test body and the vertical axis represents a circumferential direction. Moreover, a signal value is represented by a shade of color such that a higher brightness (i.e. a lighter color) represents a larger signal value.

In the detection results of the respective conventional techniques, the remainders of the noise component exist. Especially in the band pass filter method, the damage component of the processing result spreads to the circumferential direction, and the position precision is decreased. From the above, the effectiveness of the signal processing section of the present invention is shown.

- 20 -

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A signal processing apparatus for reducing noise comprising:

a 2-dimensional conversion processing section which maps an observation signal in a first coordinate system into a second orthogonal coordinate system to output a 2-dimensional converted signal, wherein said observation signal includes a detection object component and a noise component to be attenuated, and said noise component is composed of a first noise component and a second noise component;

a 2-dimensional emphasis and attenuation processing section which attenuates said first noise component of said 2-dimensional converted signal to emphasize said detection object component thereof and outputs a 2-dimensional filtered signal in which said detection object component is emphasized; and

a 2-dimensional smoothing processing section which attenuates said second noise component contained in said 2-dimensional filtered signal, and outputs a 2-dimensional smoothed signal, whereby a detection object can be detected based on said 2-dimensional smoothed signal and based on a difference between the detection object component to be detected and the noise component to be attenuated in a spatial frequency spectrum.

- 21 -

2. A signal processing apparatus according to claim 1, wherein said 2-dimensional emphasis and attenuation processing section includes a 2-dimensional digital differential filter.

3. A signal processing apparatus according to claim 1, wherein said 2-dimensional smoothing processing section includes a median filter.

Fig. 1 PRIOR ART

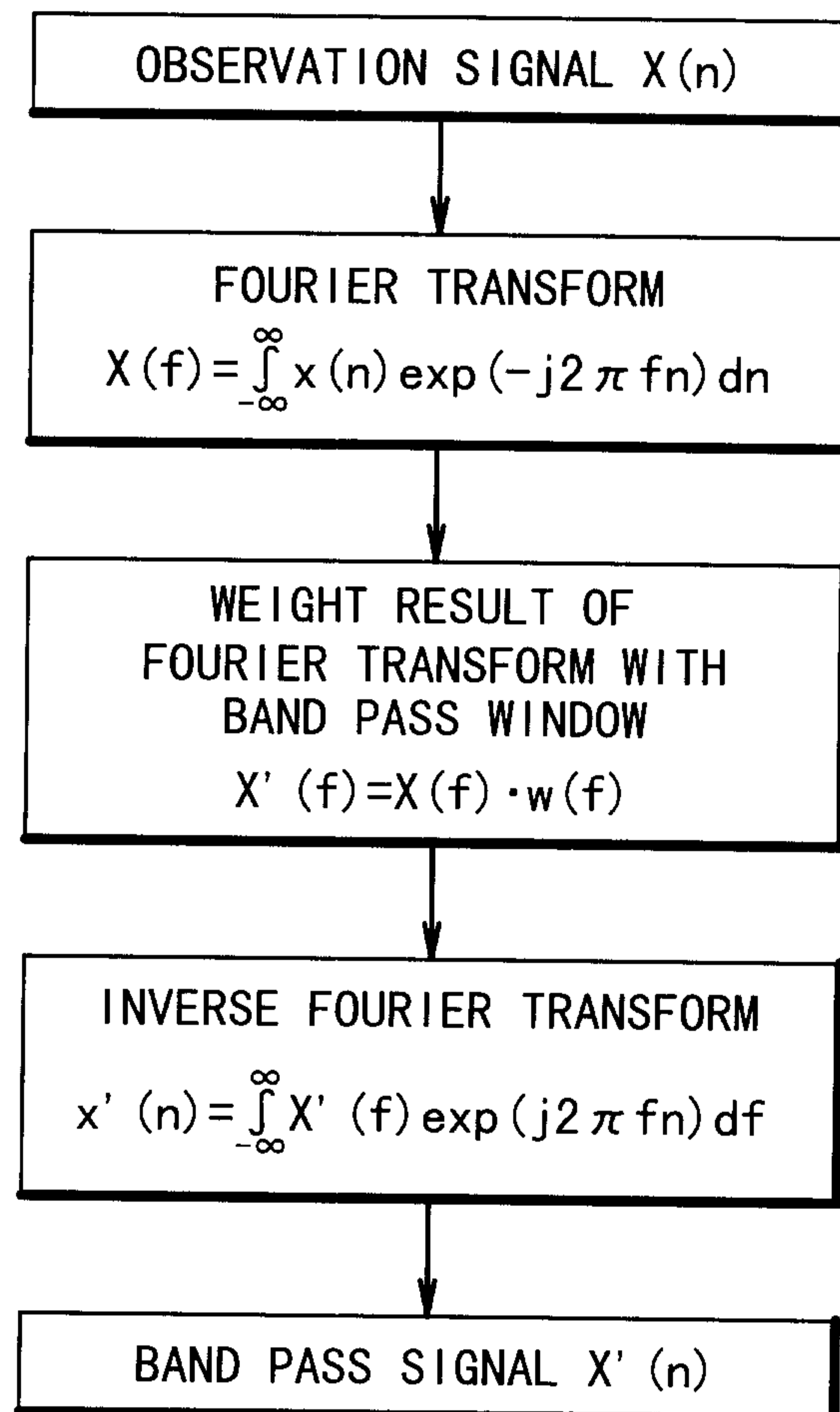


Fig. 2 PRIOR ART

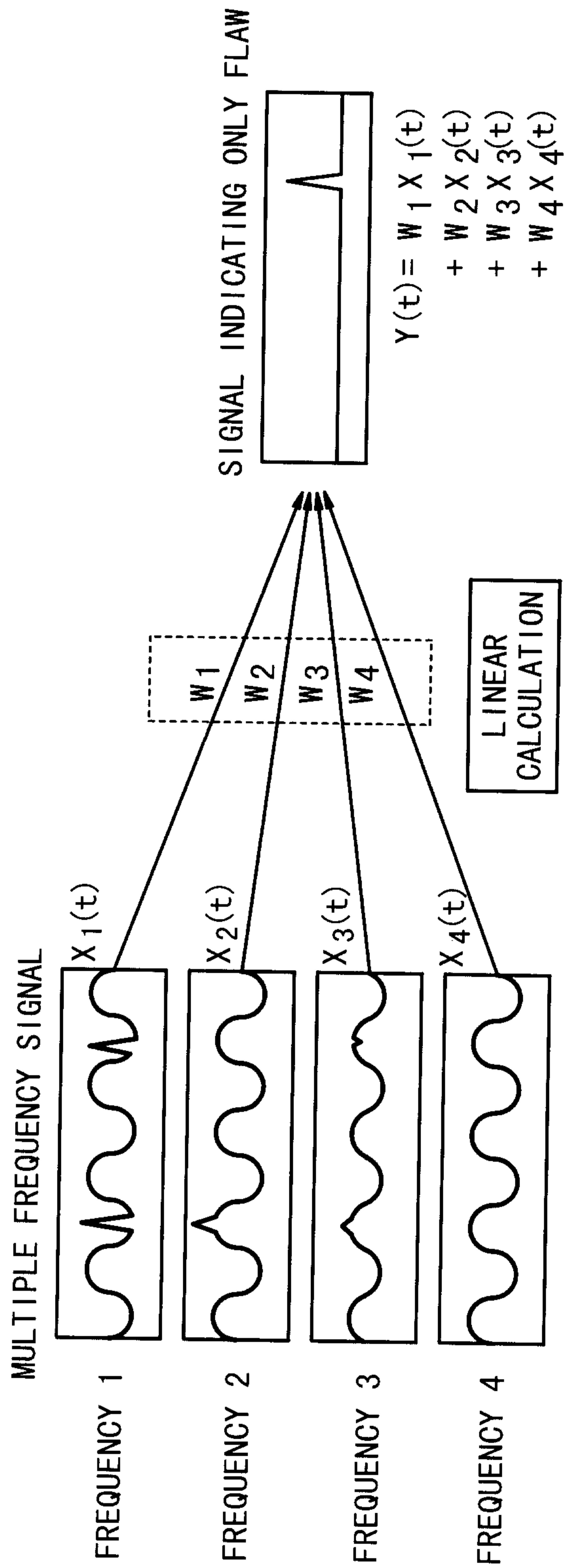


Fig. 3A
PRIOR ART

Fig. 3B
PRIOR ART

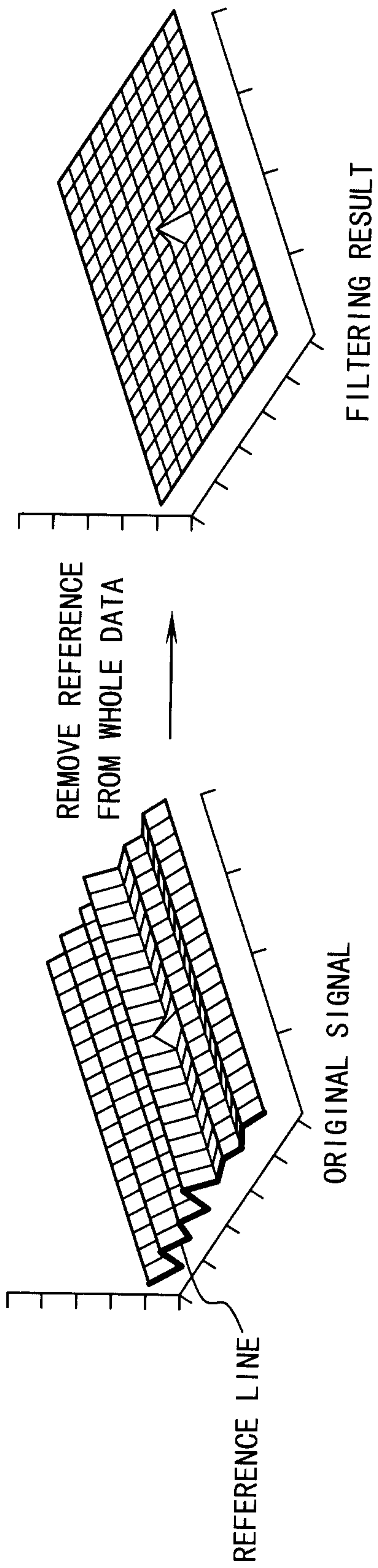


Fig. 4

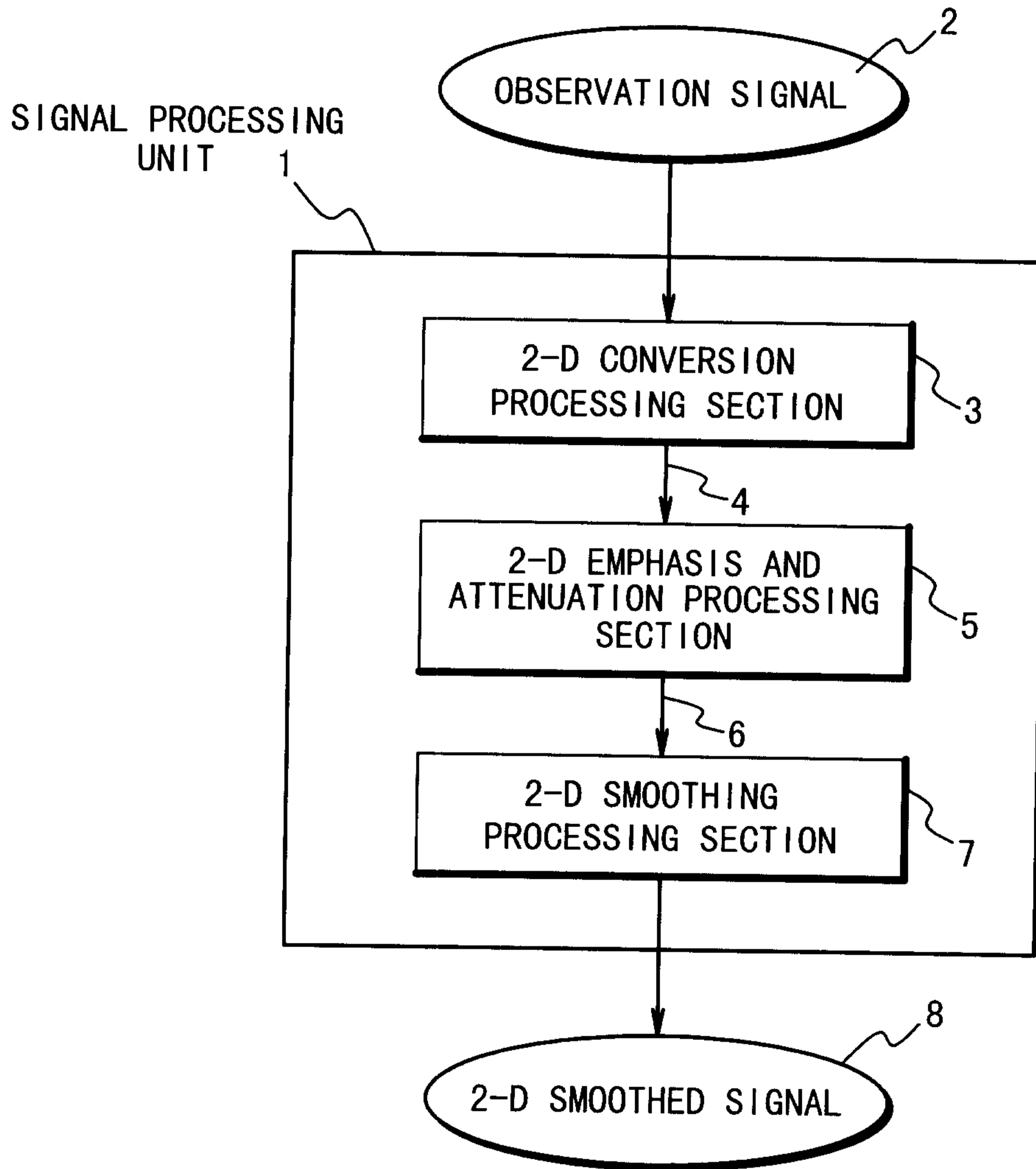


Fig. 5A

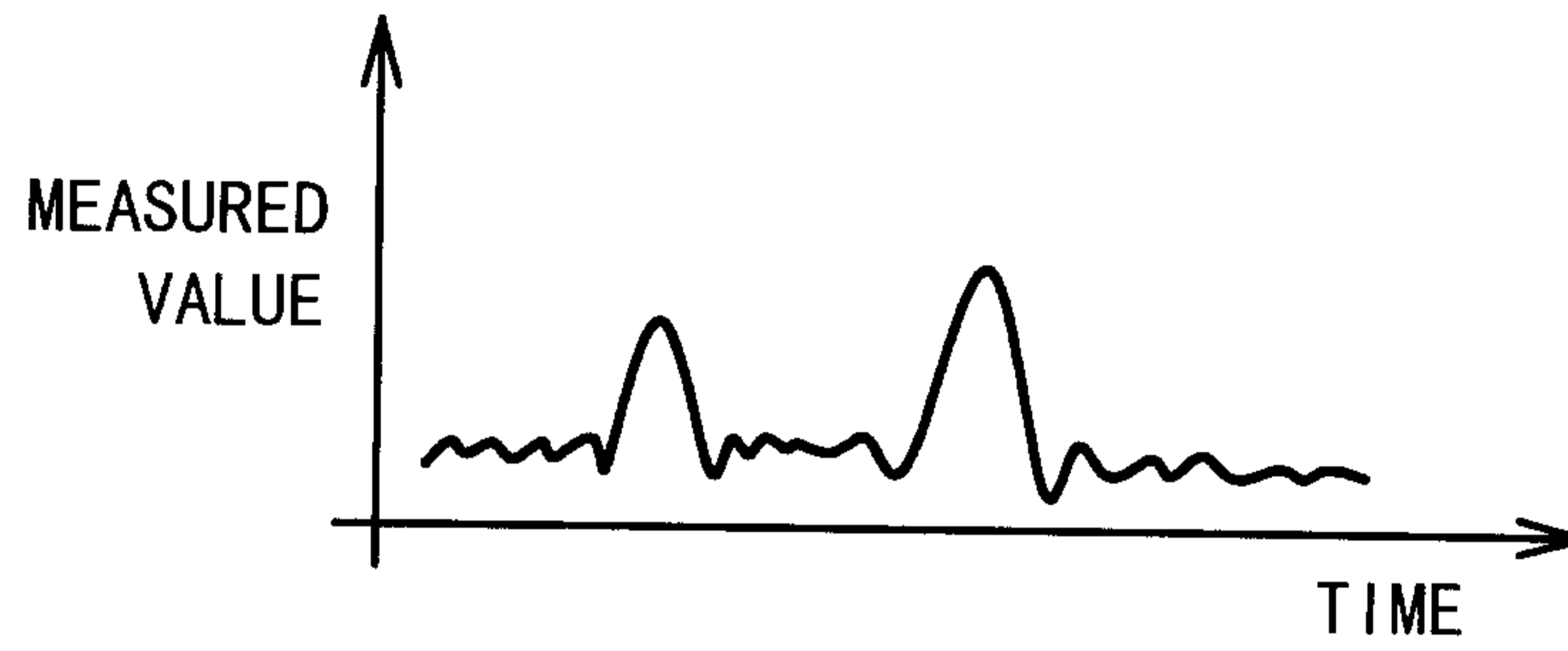


Fig. 5B

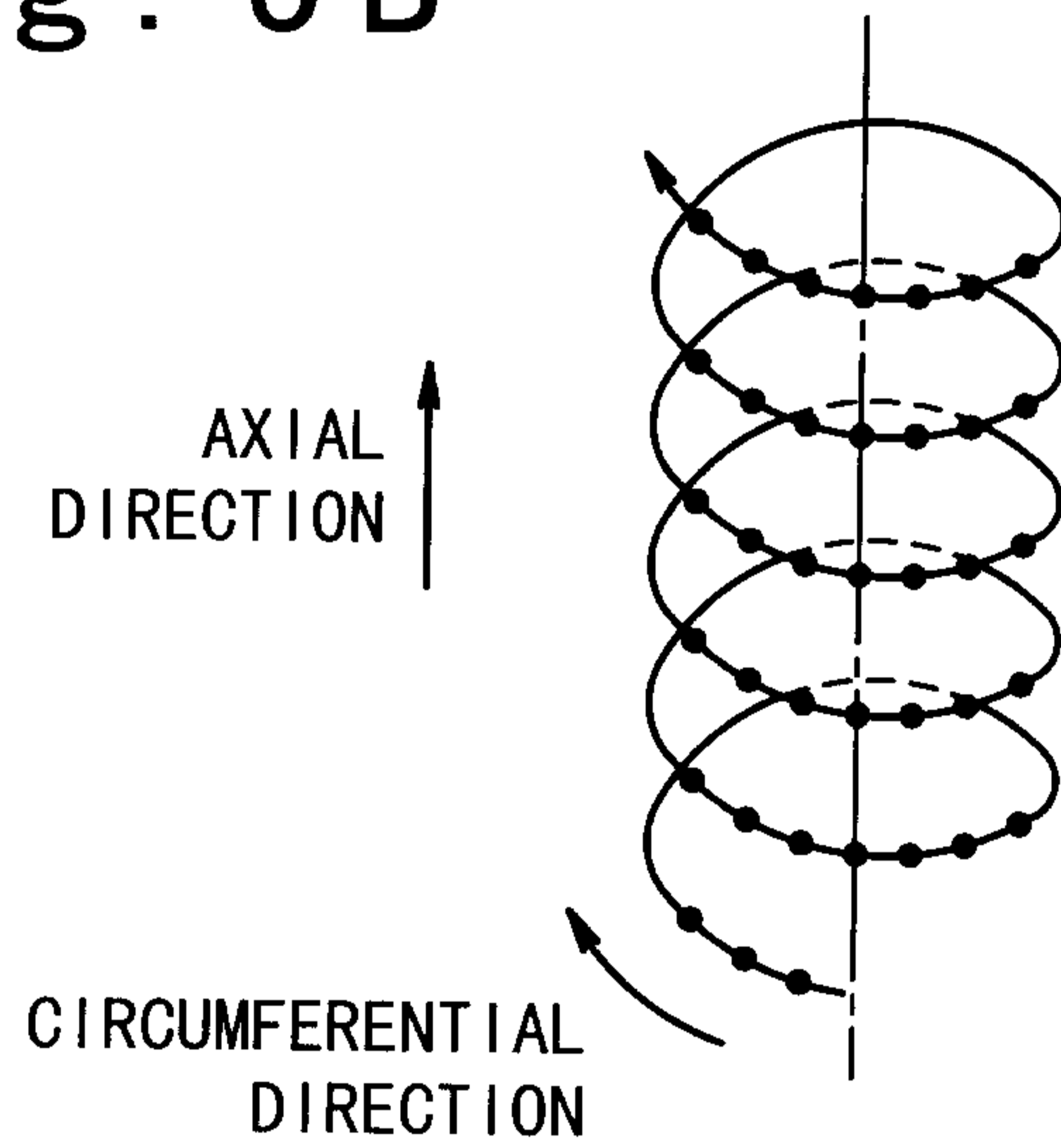


Fig. 5C

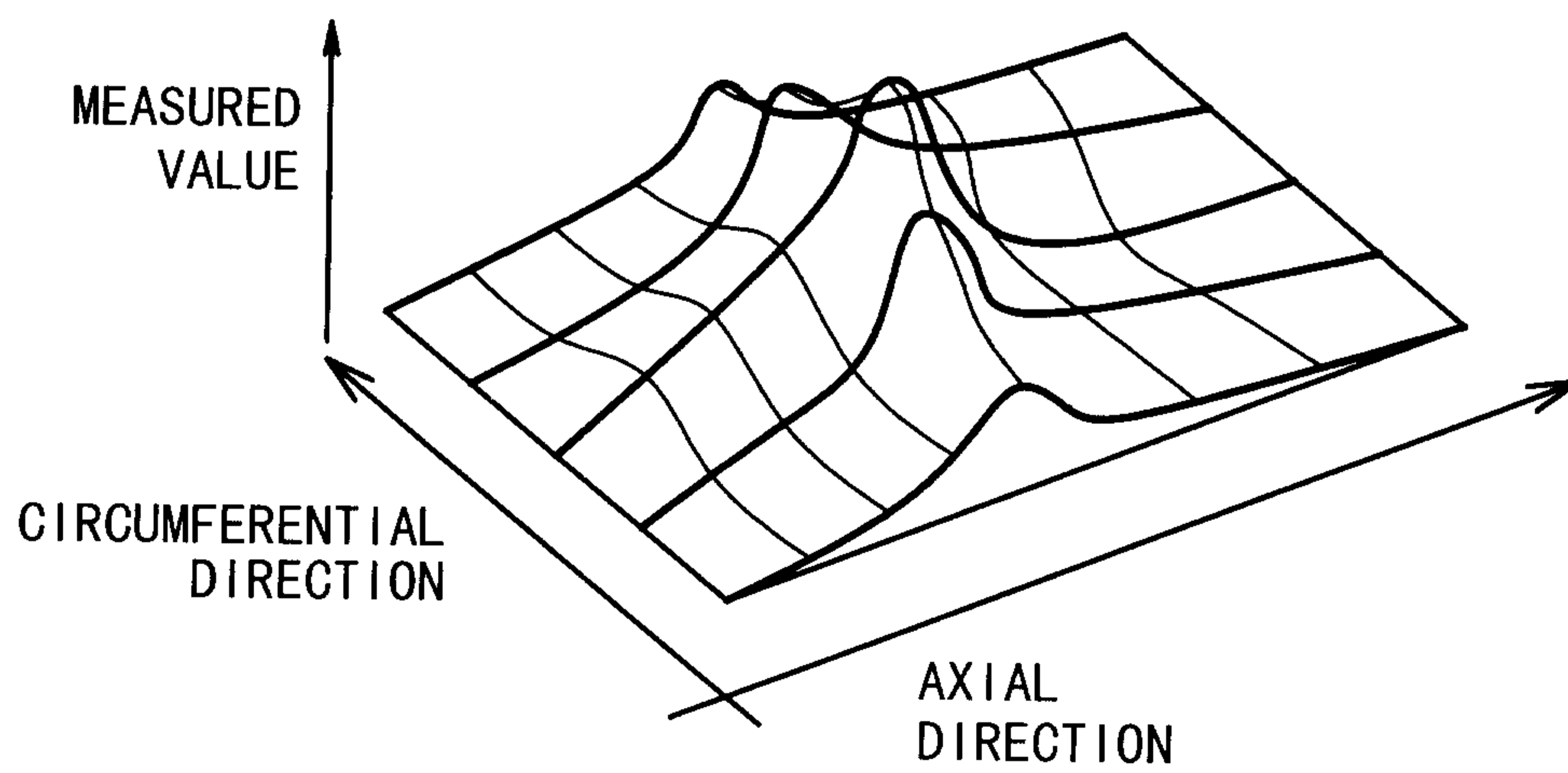


Fig. 6A

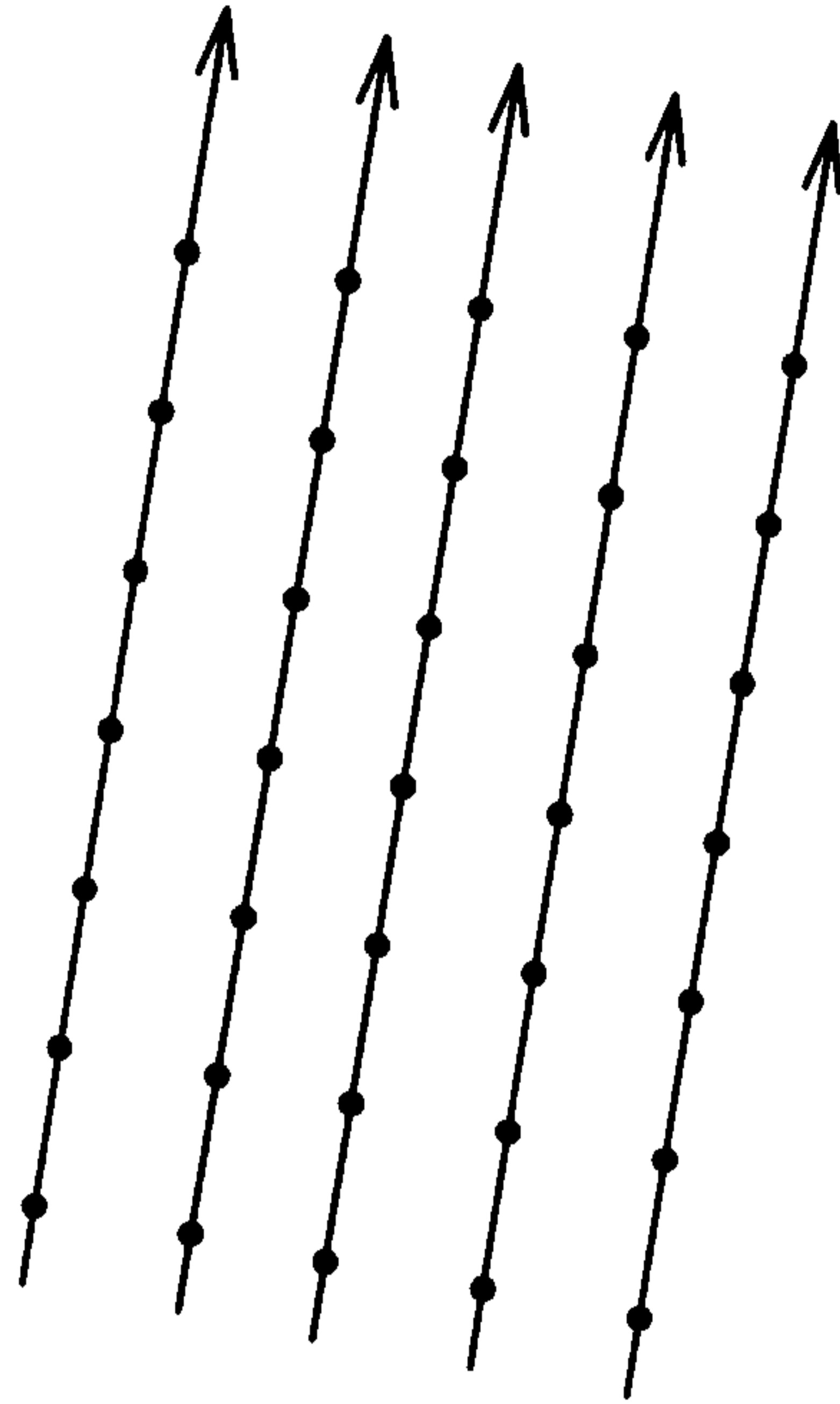


Fig. 6B

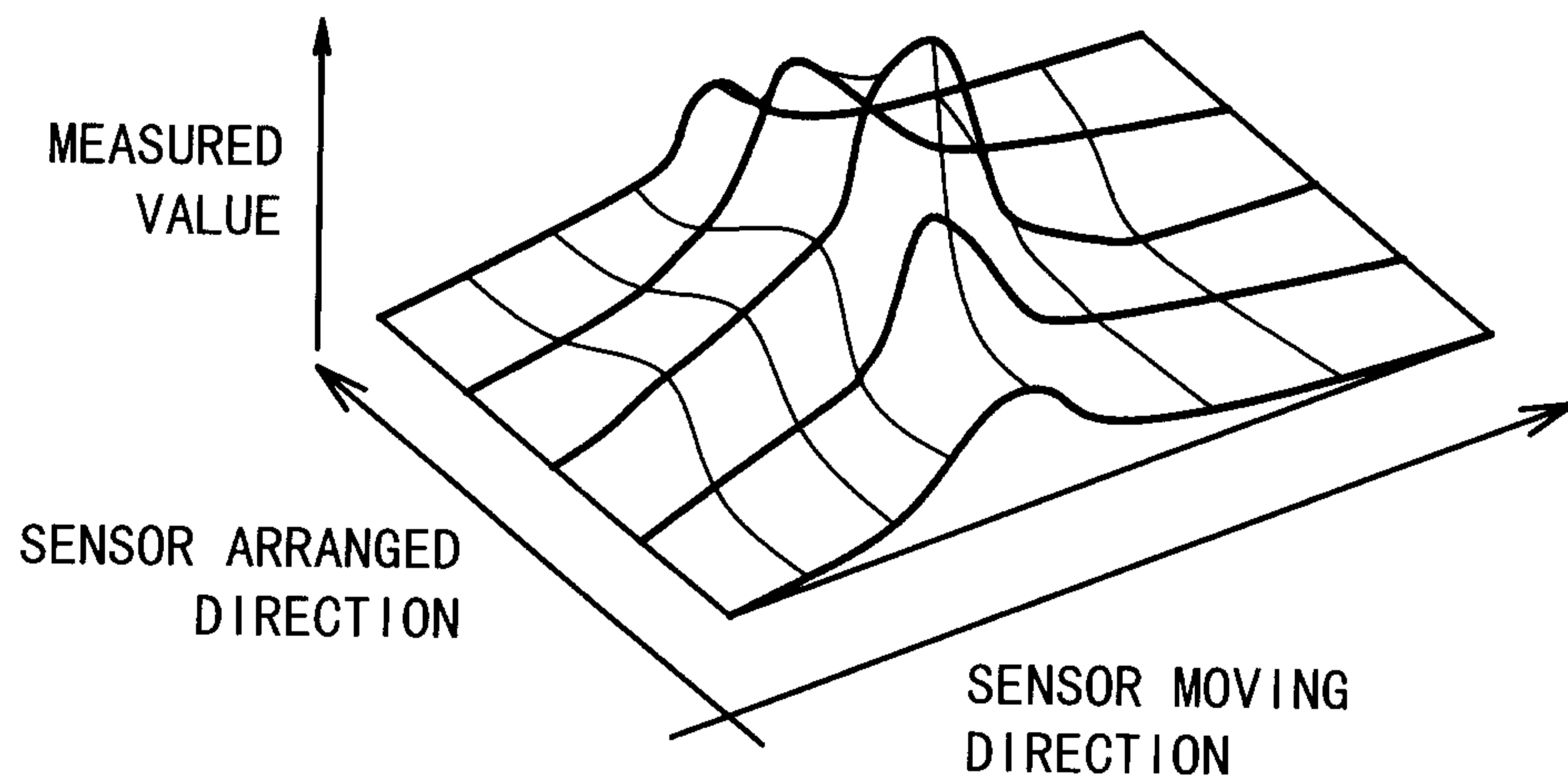


Fig. 7A

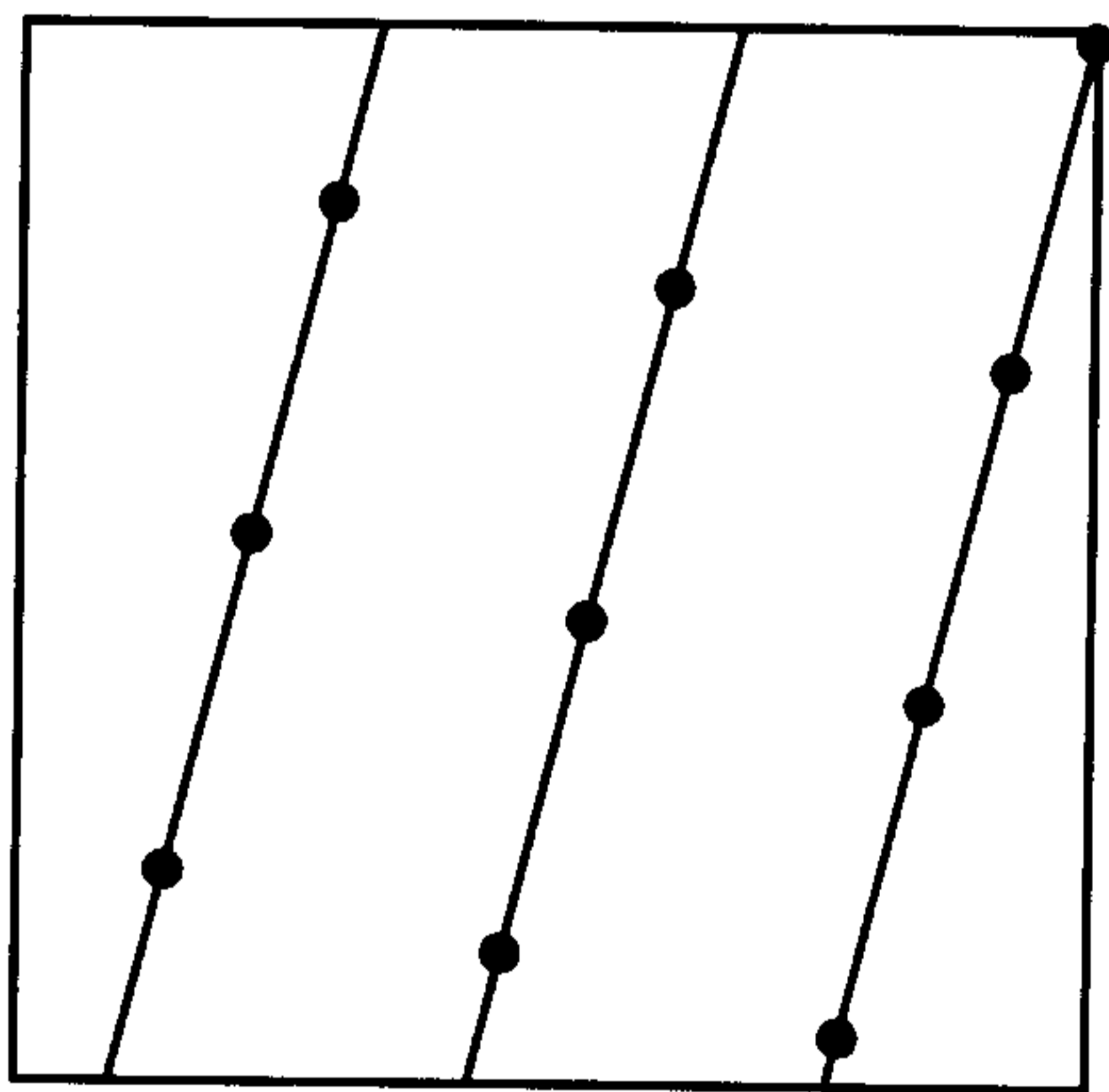


Fig. 7B

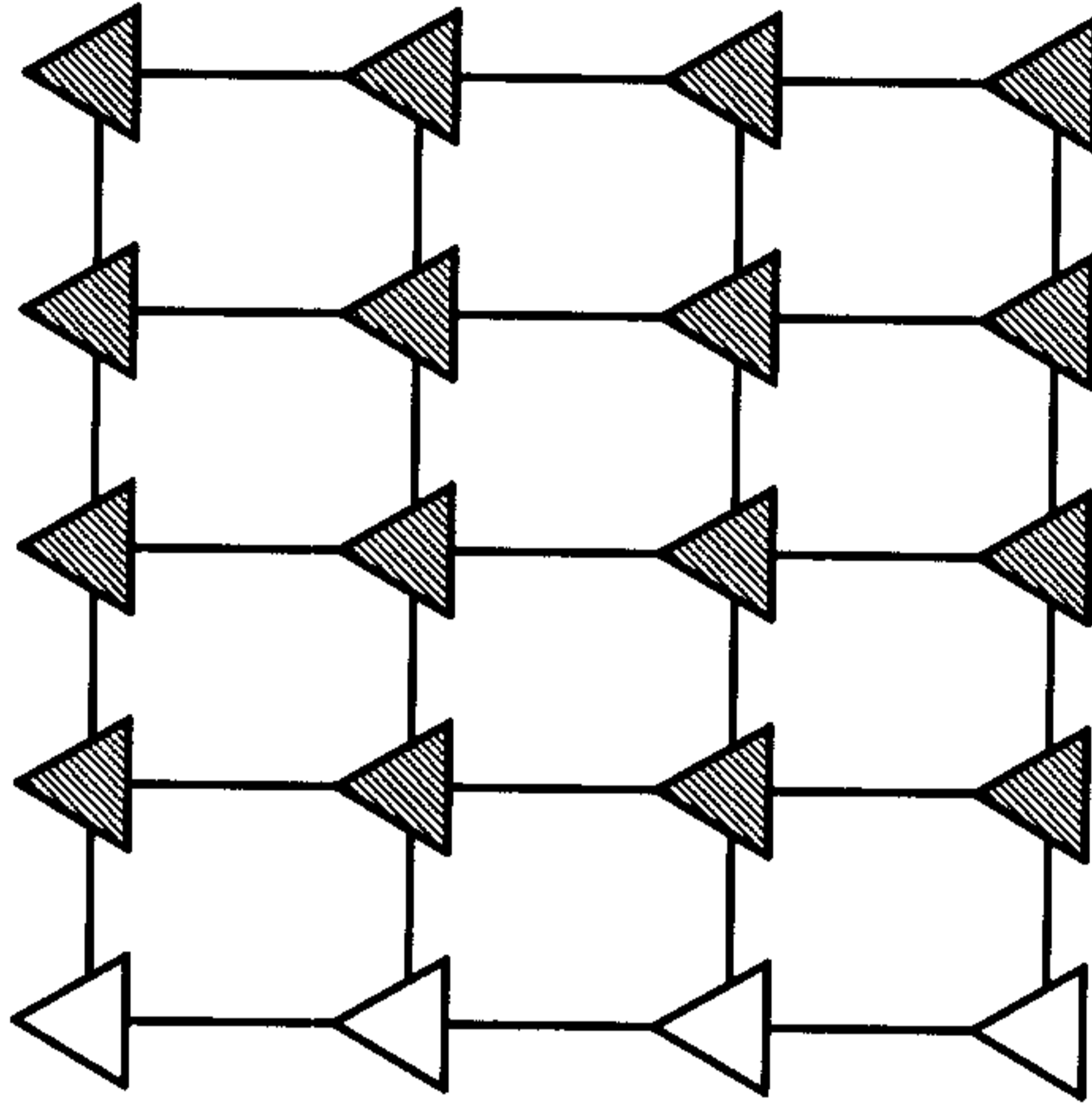


Fig. 8

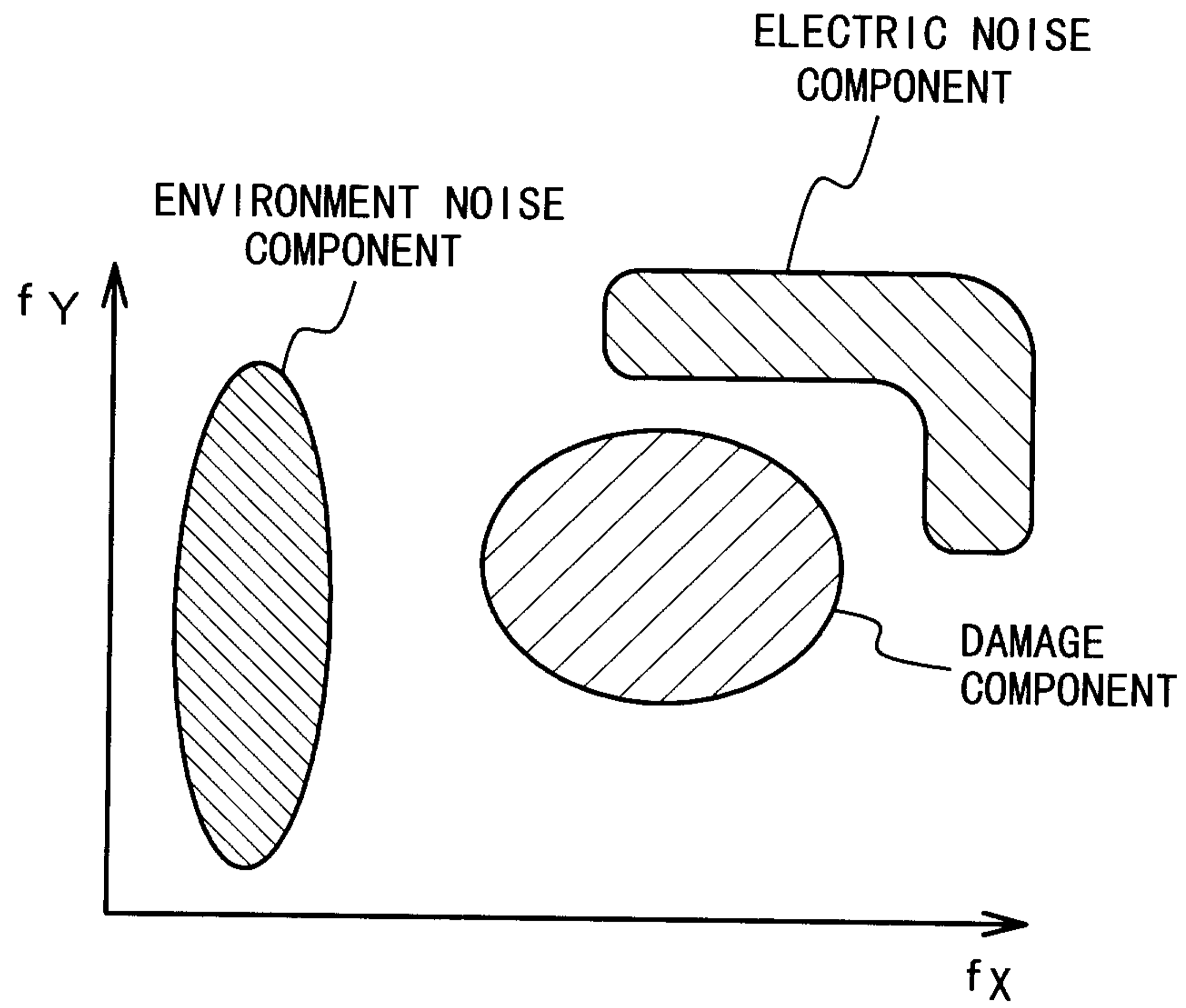


Fig. 9A

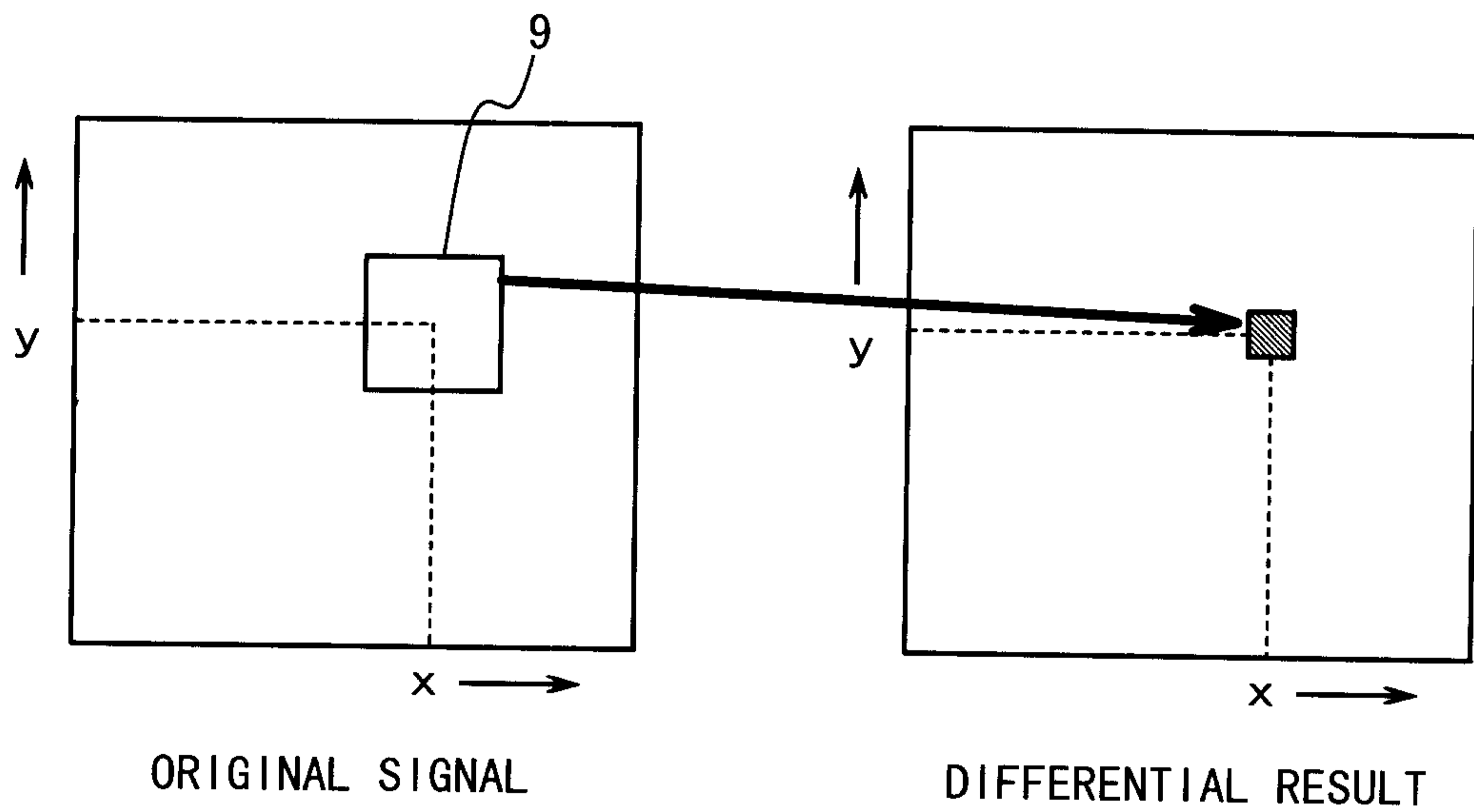


Fig. 9B

	-1	
-1	4	-1
	-1	

Fig. 10A

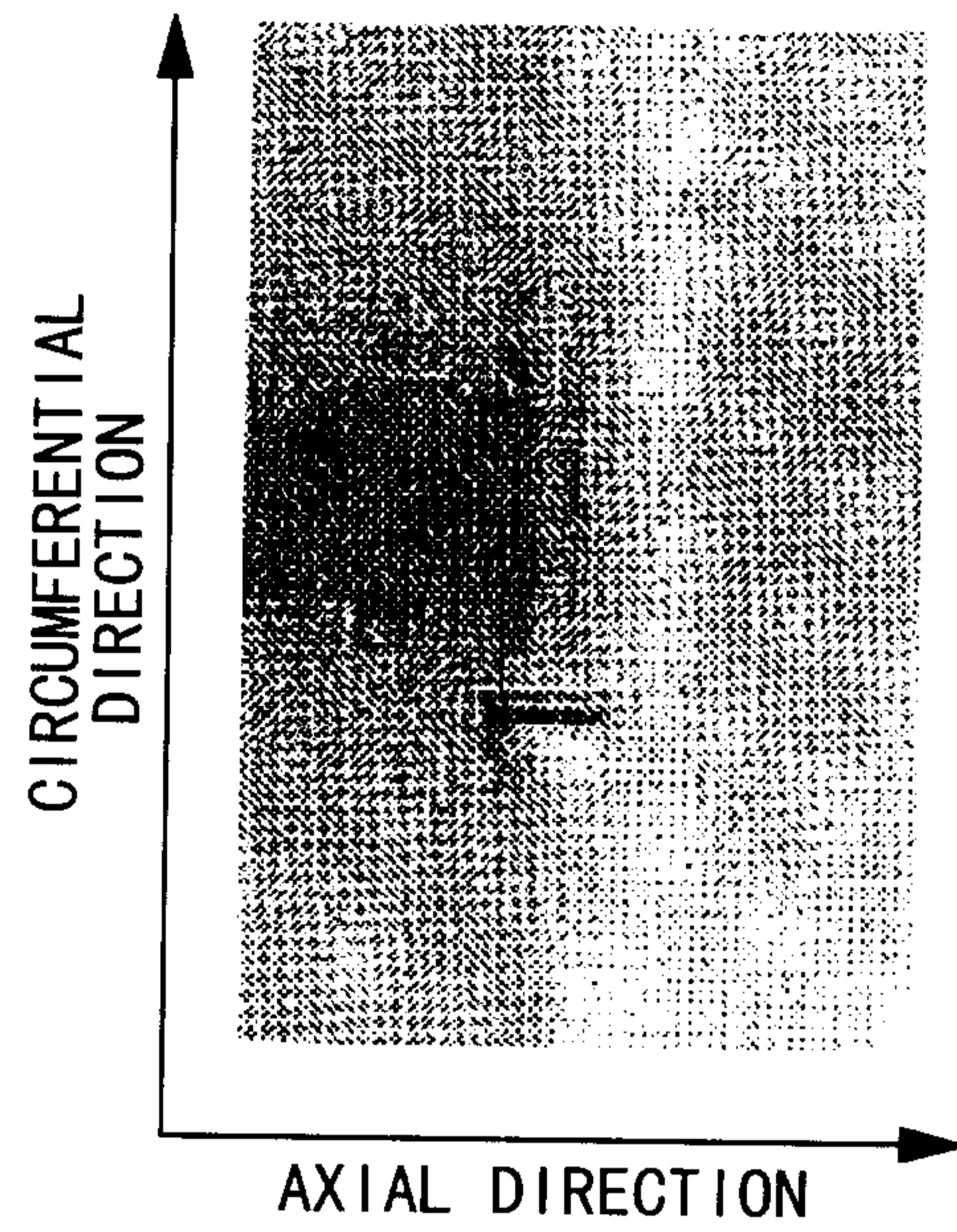


Fig. 10B

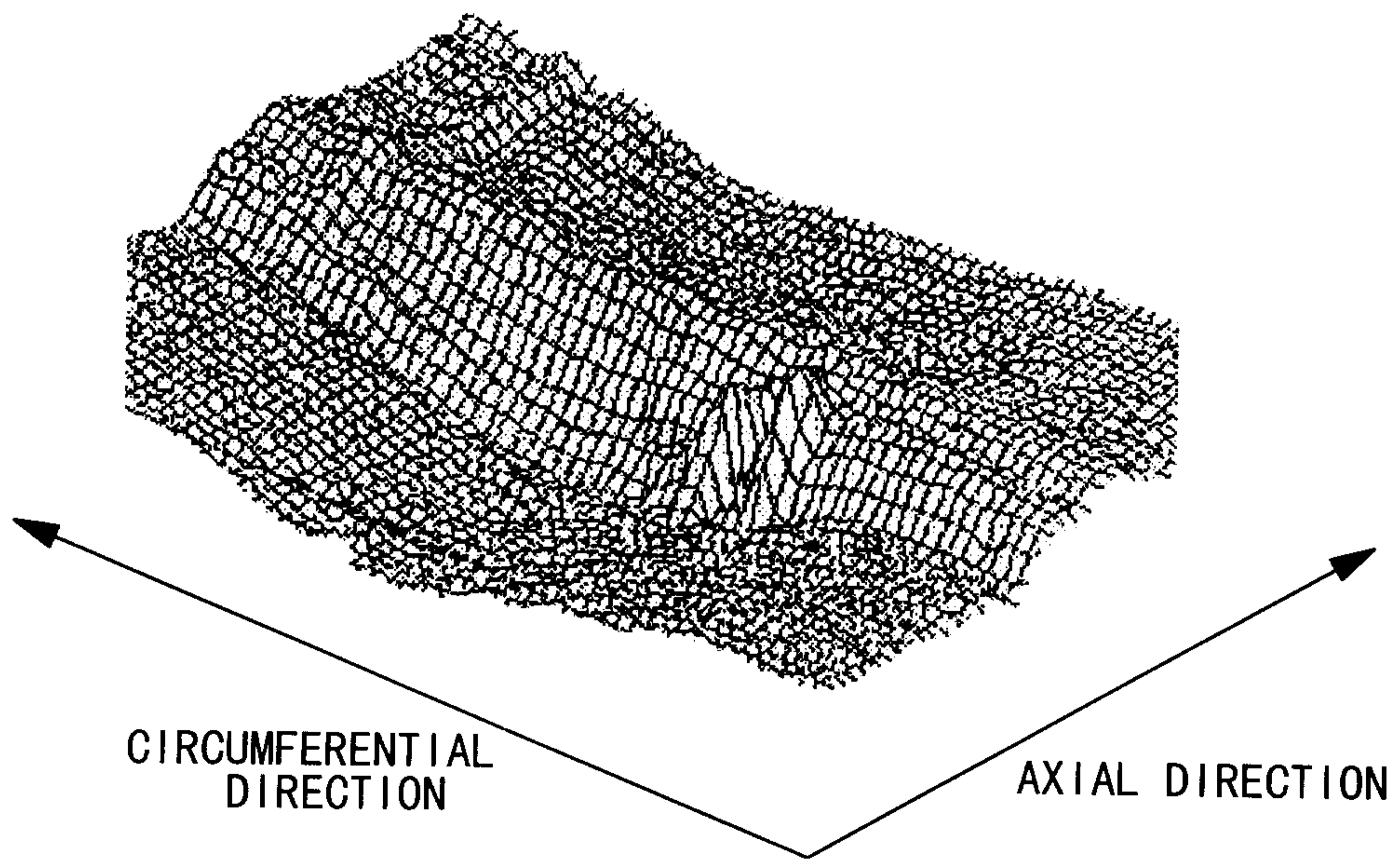


Fig. 11A

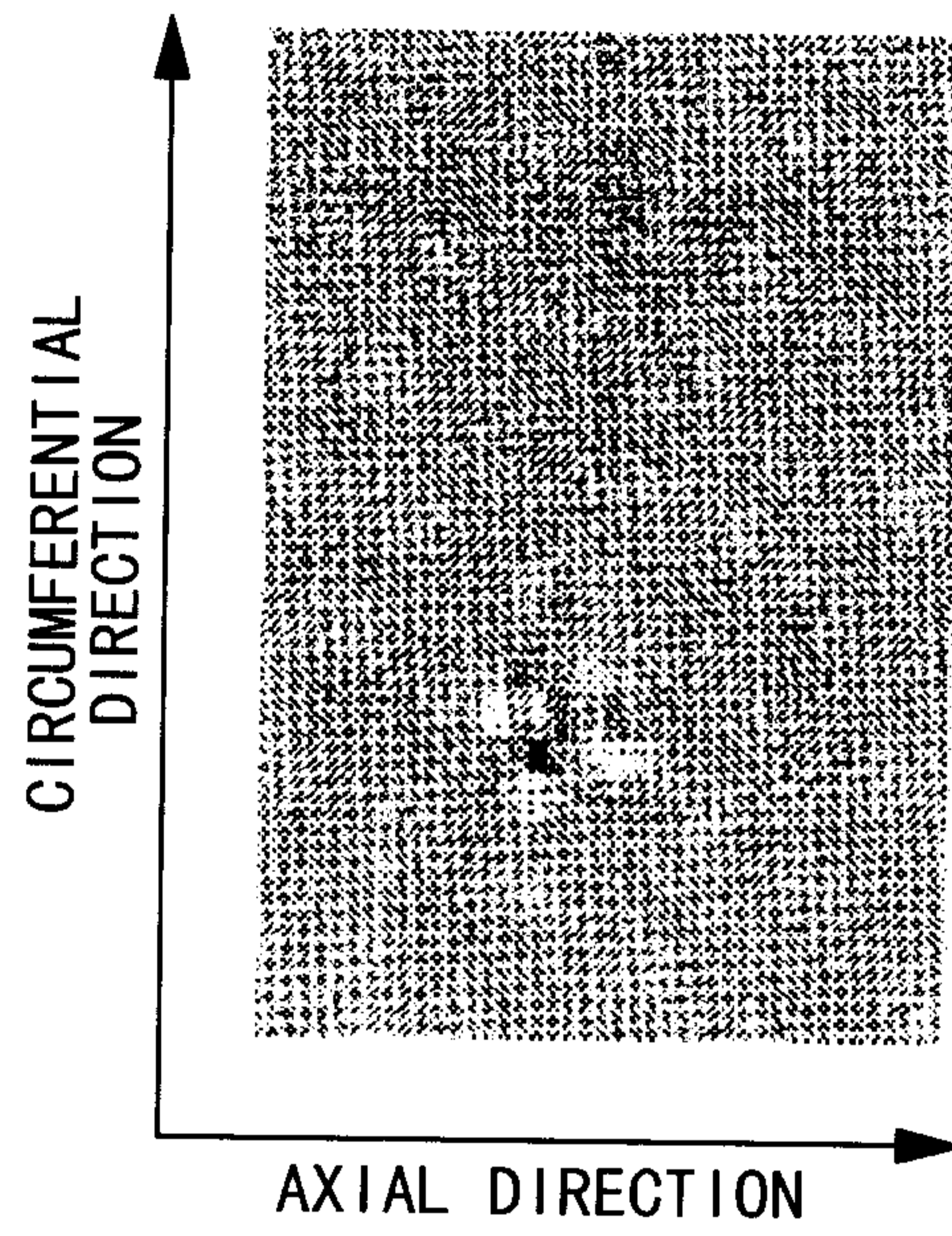


Fig. 11B

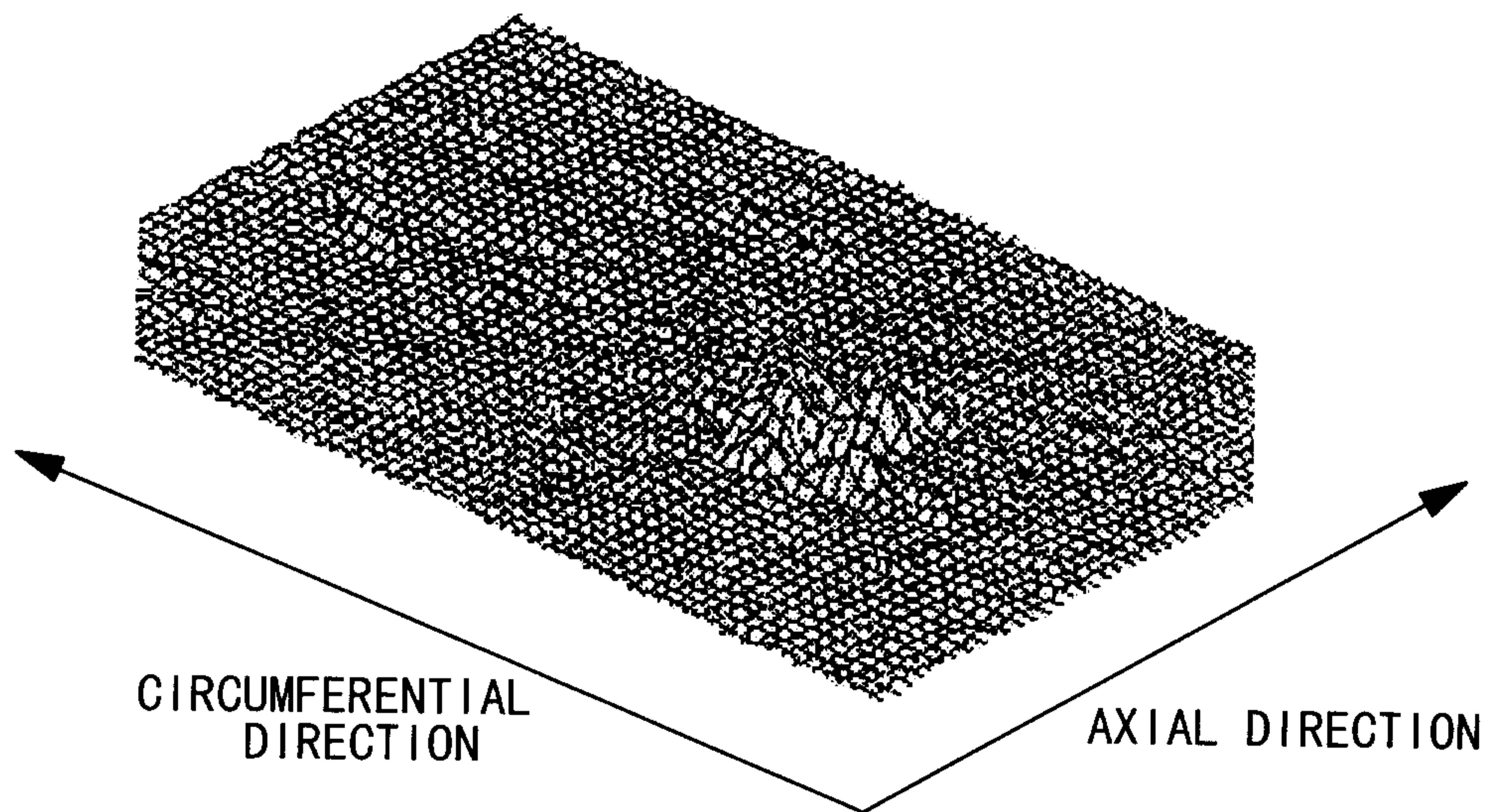


Fig. 12A PRIOR ART

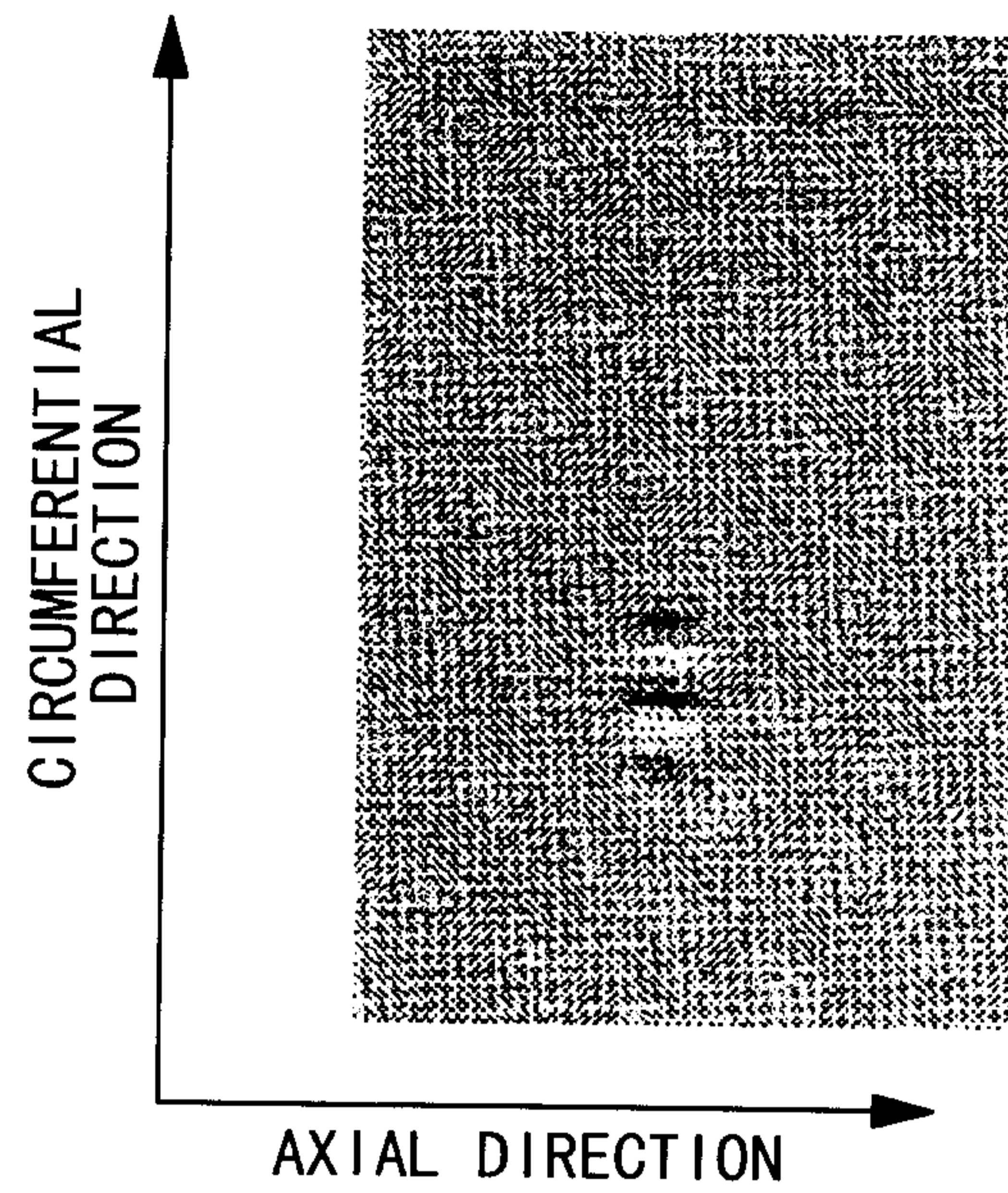


Fig. 12B PRIOR ART

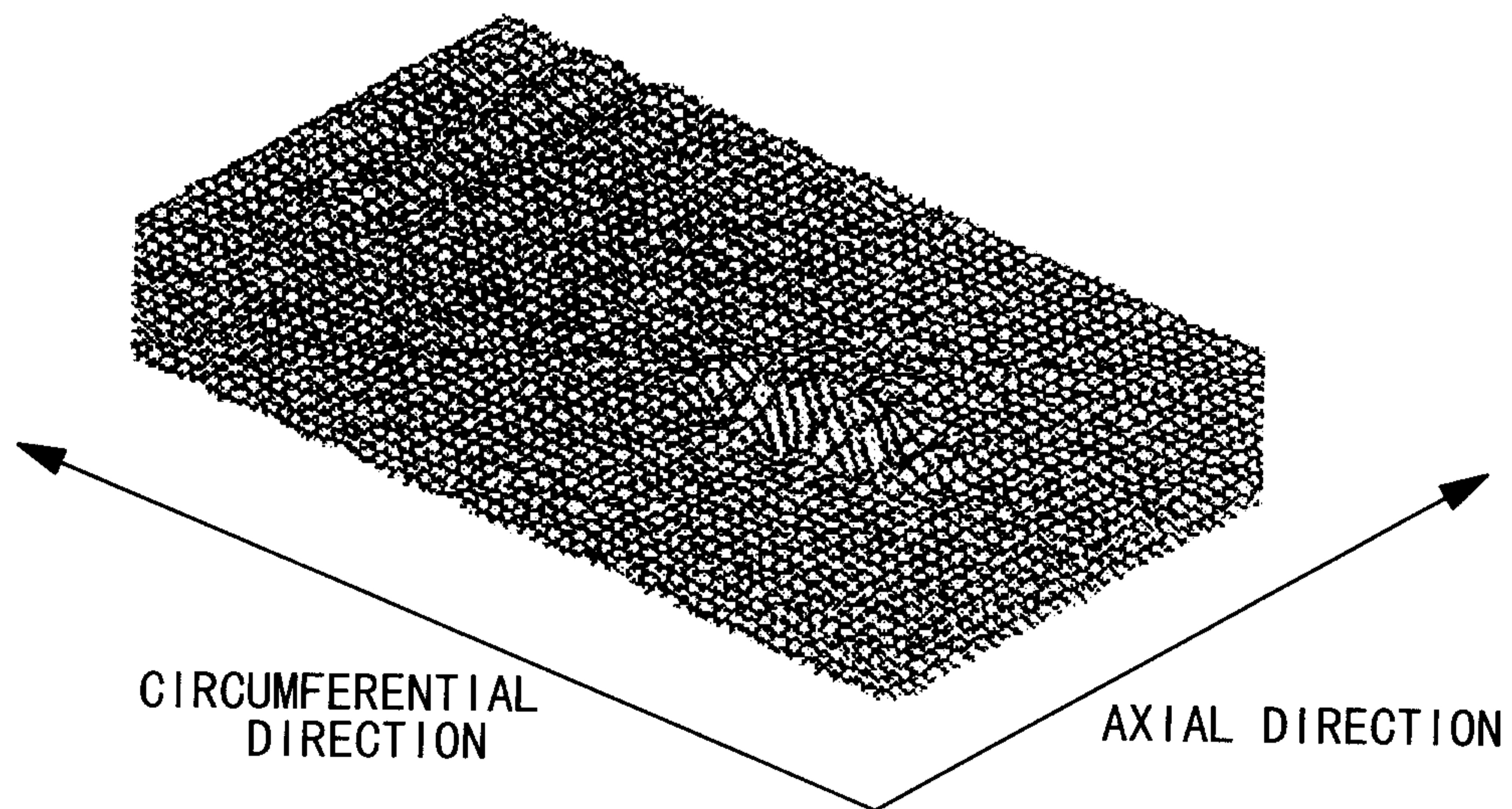


Fig. 13A PRIOR ART

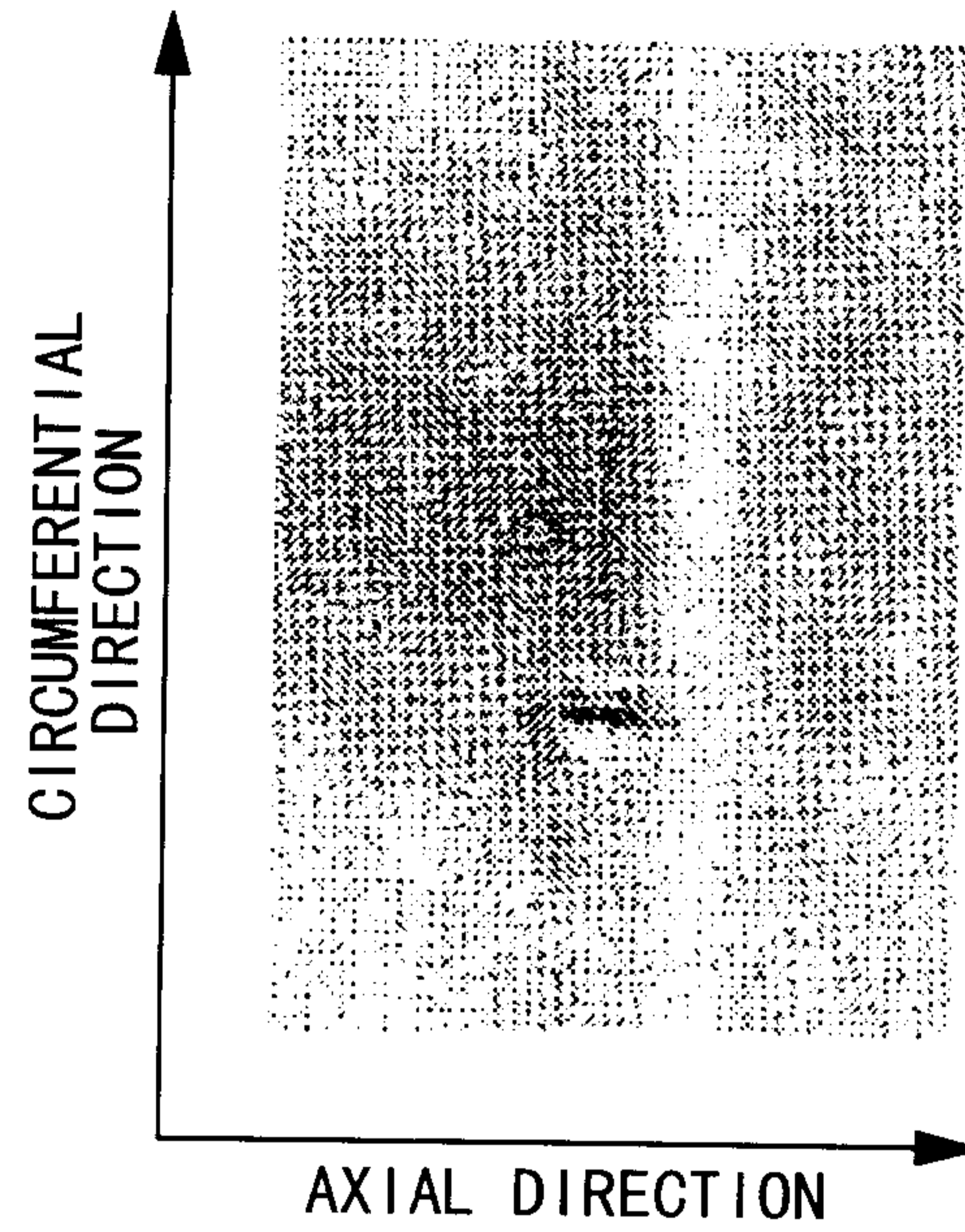


Fig. 13B PRIOR ART

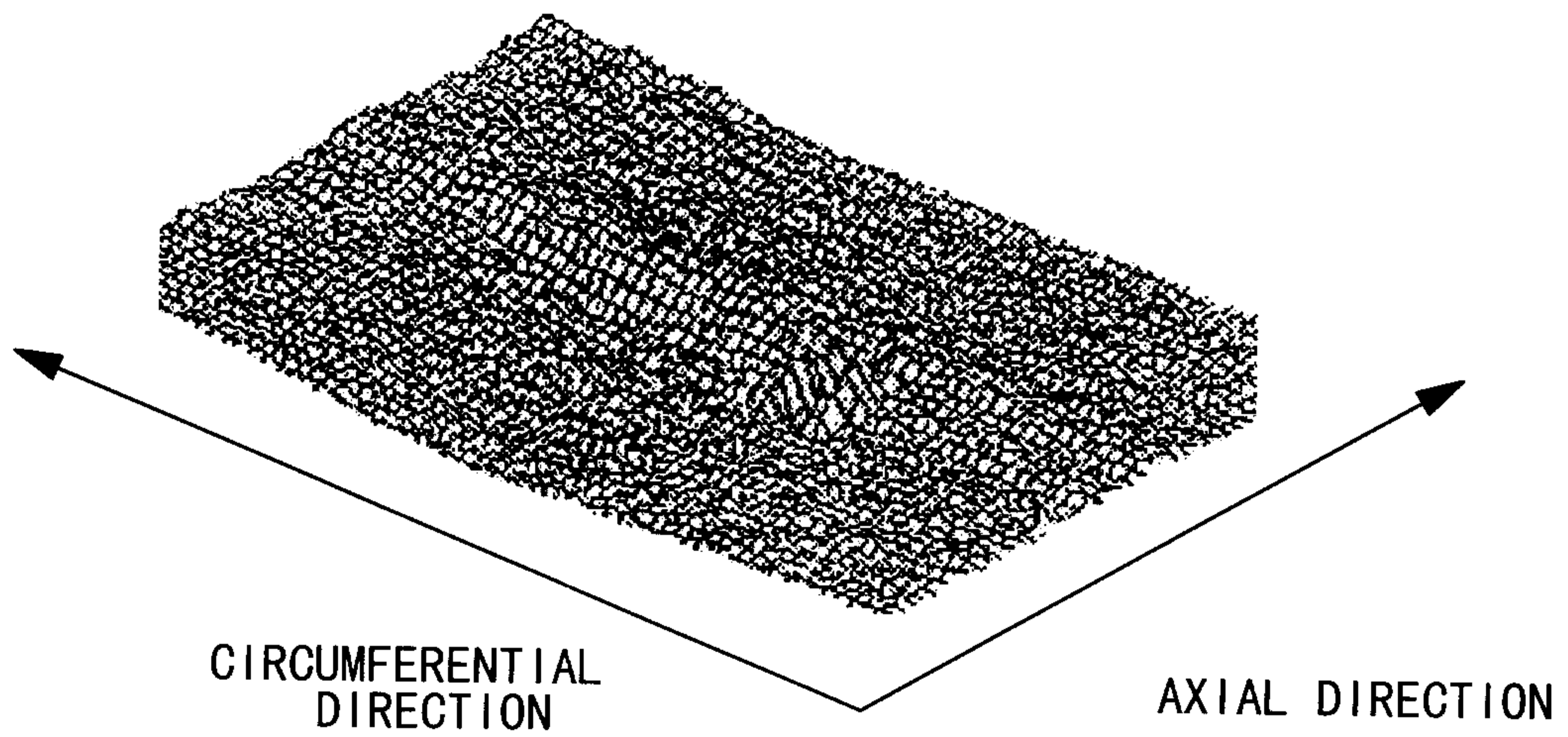


Fig. 14A PRIOR ART

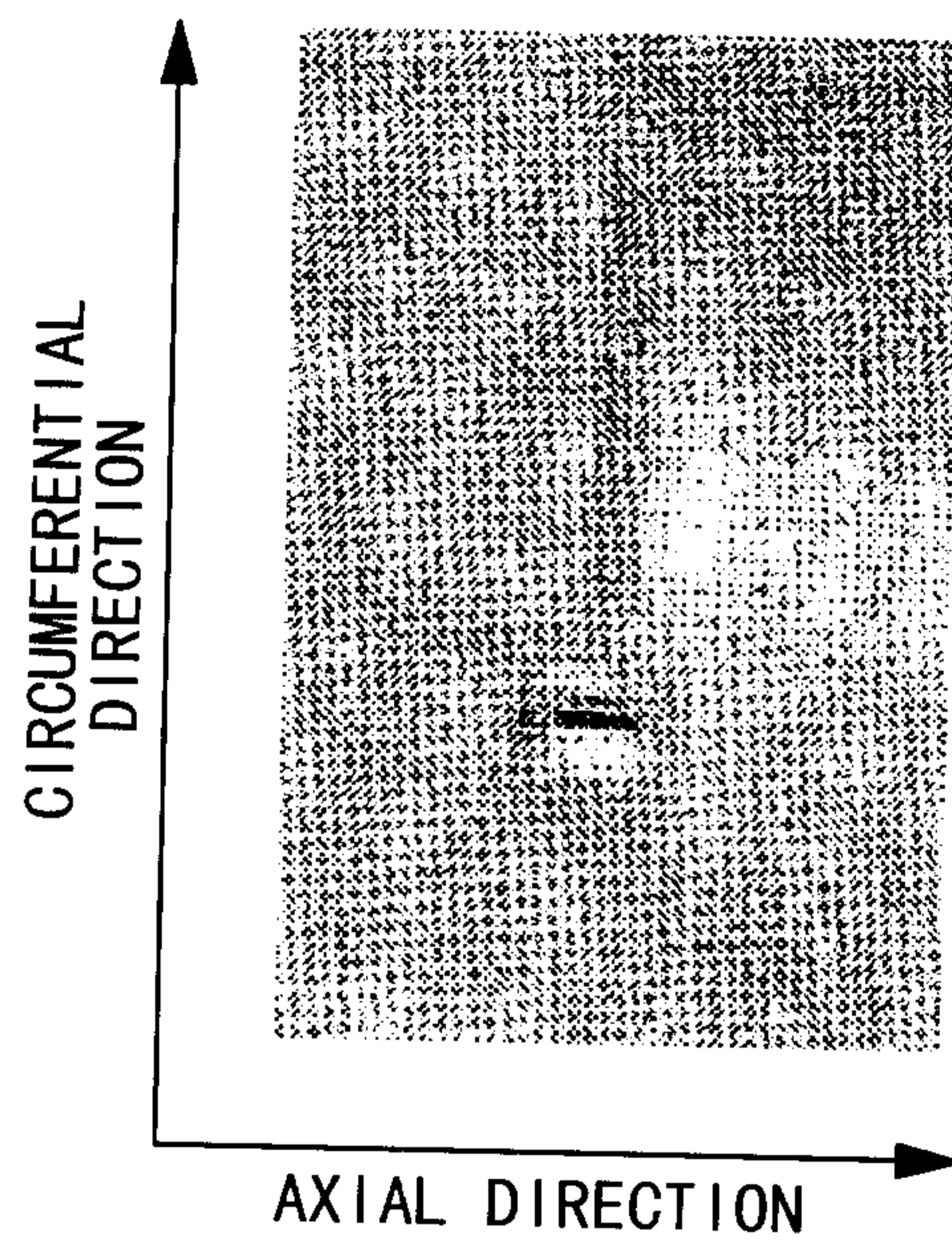


Fig. 14B PRIOR ART

