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[54] ULTRASONIC DIAGNOSTIC SCANNING FOR THREE DIMENSIONAL DISPLAY

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[52] **U.S. Cl.** **600/447**

[58] **Field of Search** 128/916; 600/443, 600/442

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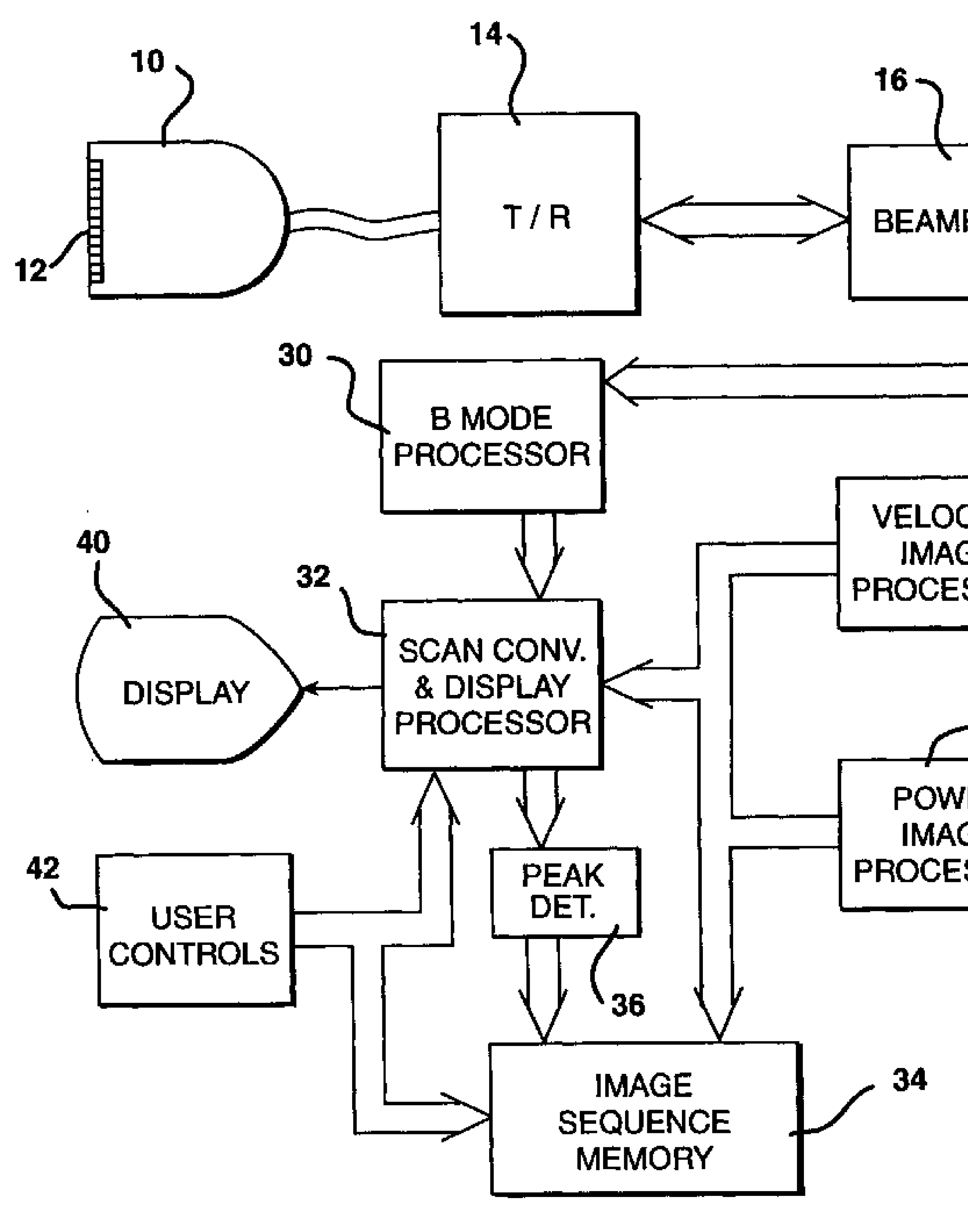
Assistant Examiner—Maulin Patel
Attorney, Agent, or Firm—W. Brinton Yorks, Jr.

[57] **ABSTRACT**

An ultrasonic diagnostic system and scanning technique are described for producing three dimensional ultrasonic image displays utilizing power Doppler signal information. In a preferred embodiment the power Doppler signal information is displayed in the absence of structural (B mode) information to reduce image clutter and provide three dimensional image segmentation. An ultrasonic scanning technique is presented for acquiring diagnostic three dimensional ultrasonic images of power Doppler intensity through manual hand scanning of a patient, without the need for specially fabricated scanning mechanisms or devices.

50 Claims, 6 Drawing Sheets



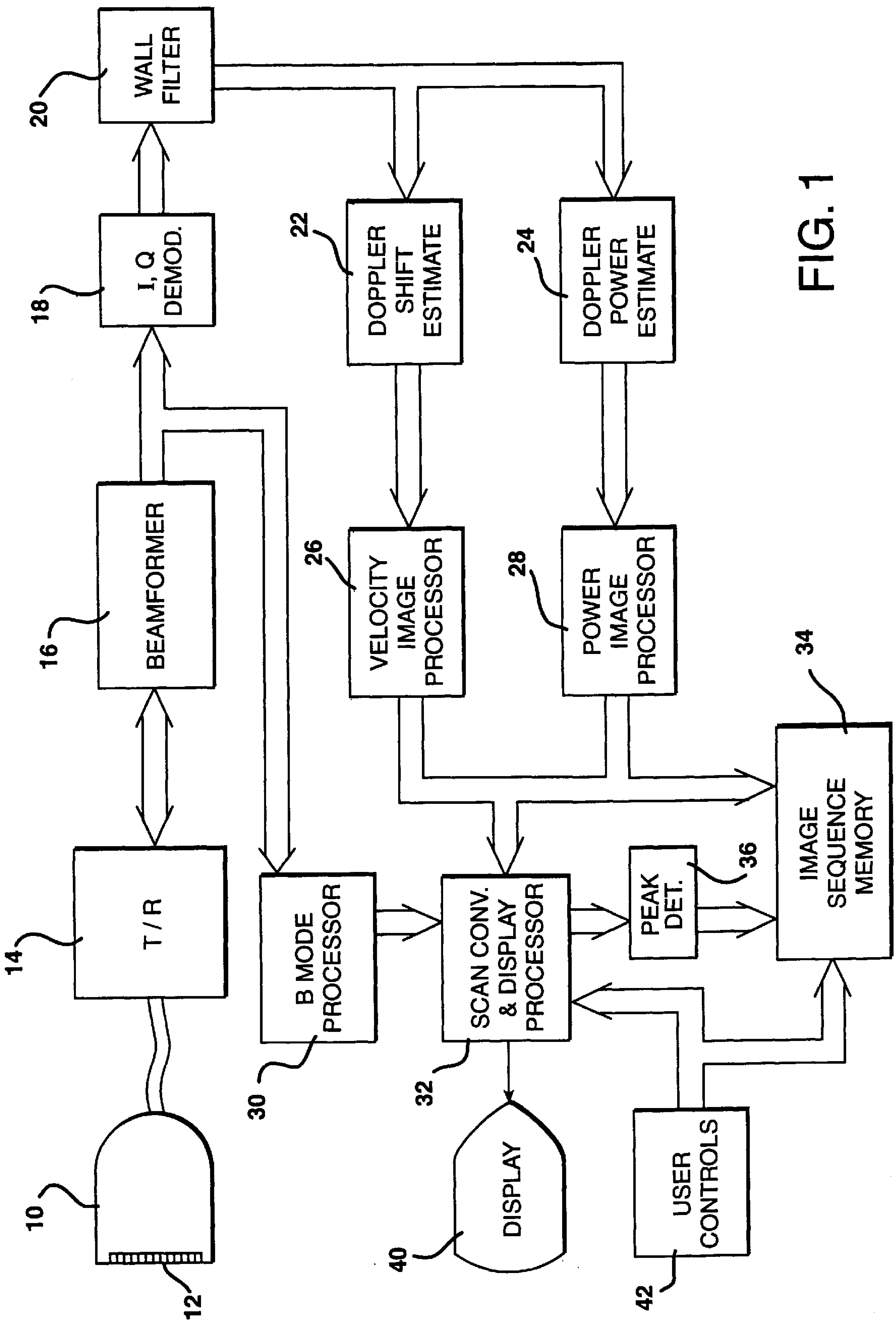
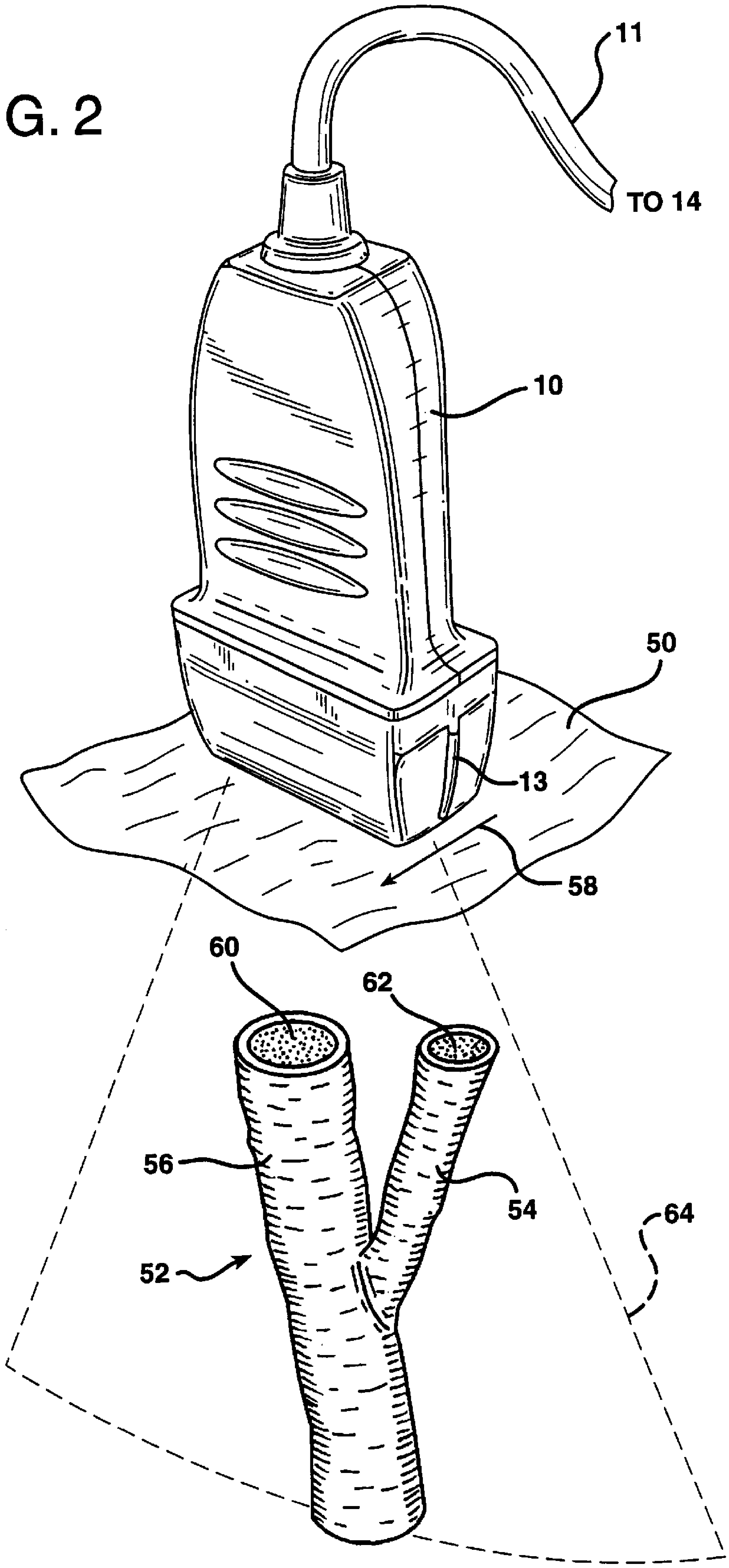

WALL FILTER
20
I, Q DEMOD.
18
BEAMFORMER
16
T / R
14
10
12
DOPPLER SHIFT ESTIMATE
22
DOPPLER POWER ESTIMATE
24
VELOCITY IMAGE PROCESSOR
26
POWER IMAGE PROCESSOR
28
B MODE PROCESSOR
30
SCAN CONV. & DISPLAY PROCESSOR
32
PEAK DET.
36
IMAGE SEQUENCE MEMORY
34
DISPLAY
40
USER CONTROLS
42

FIG. 1

FIG. 2



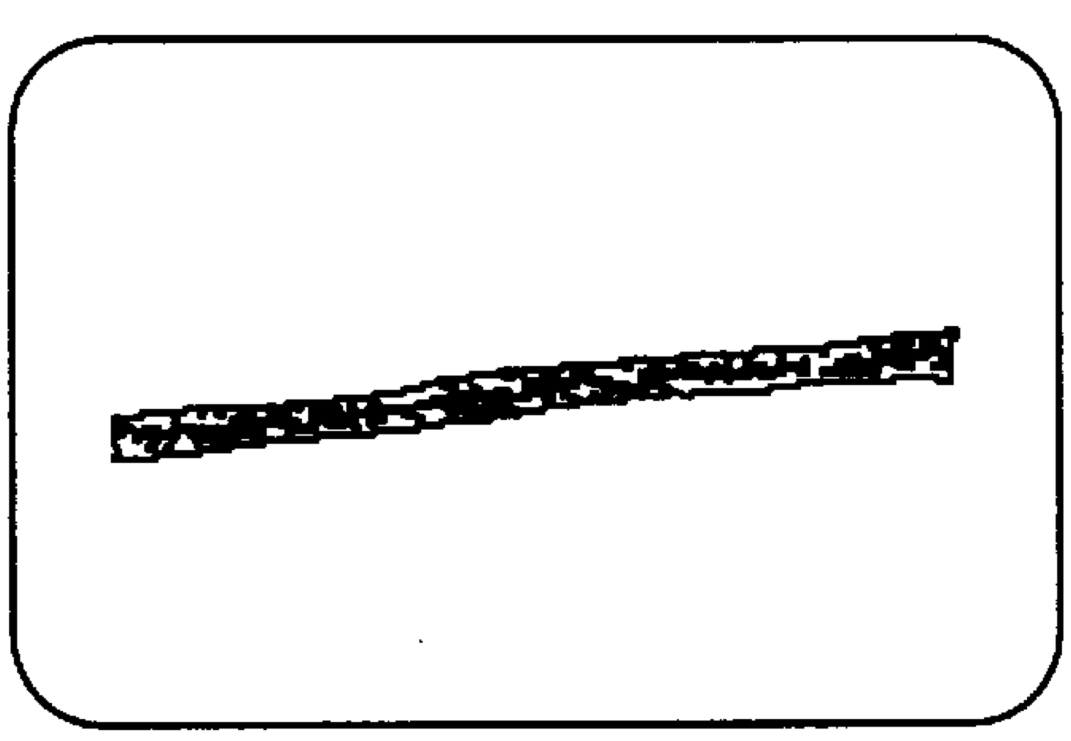


FIG. 3a

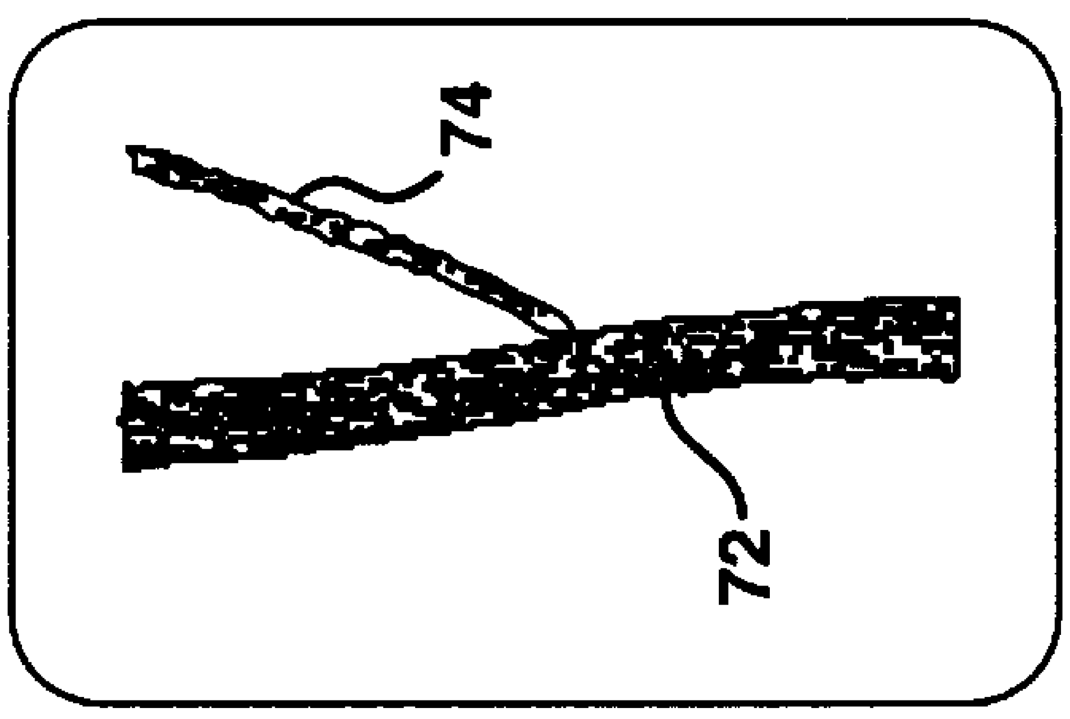


FIG. 3b

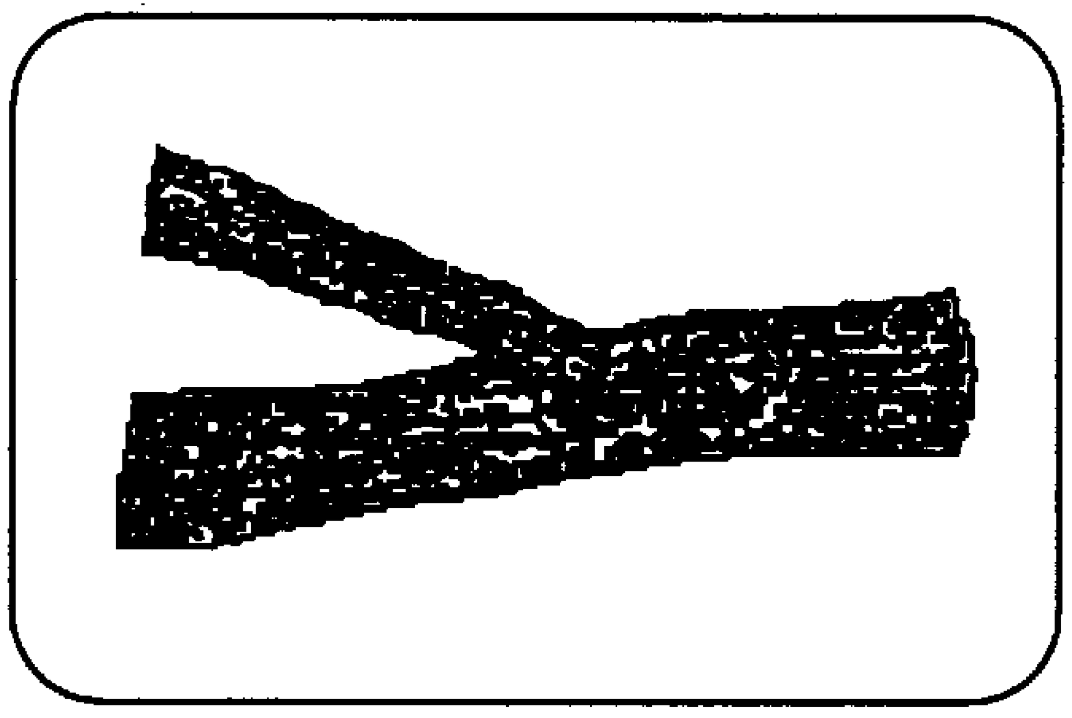


FIG. 3c

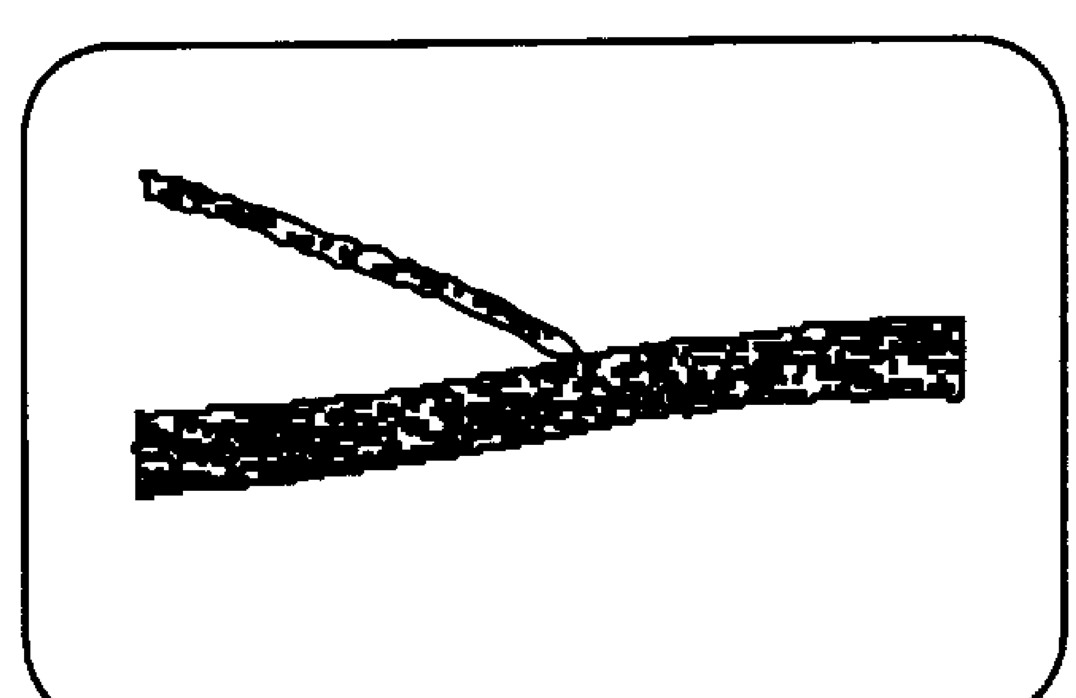


FIG. 3d

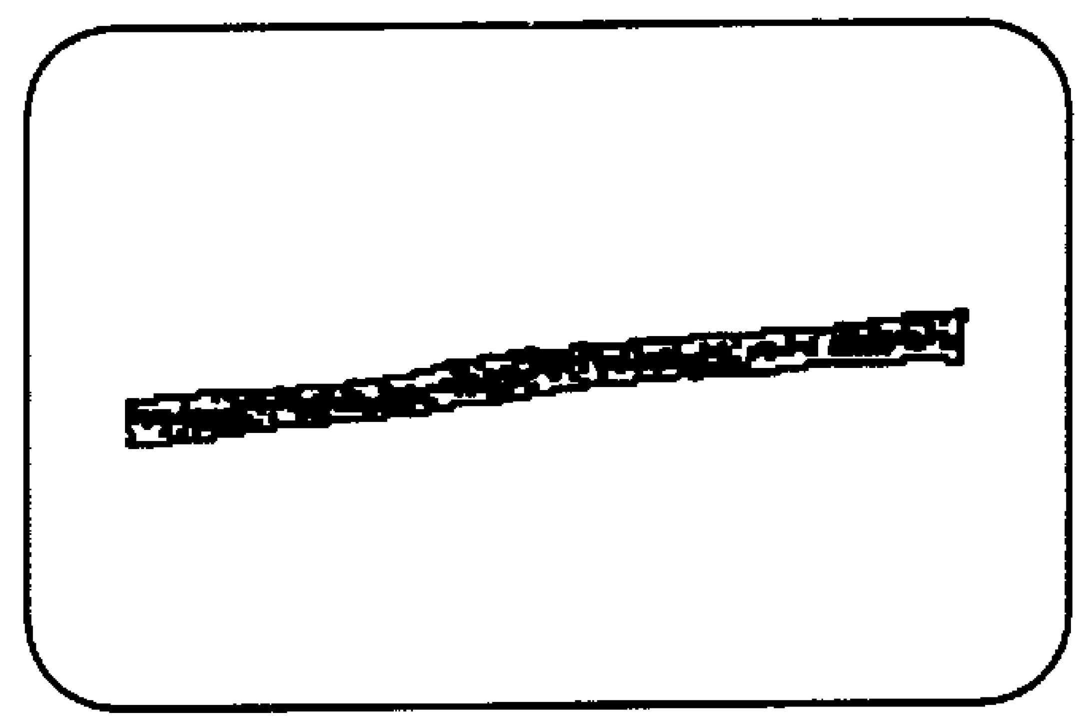


FIG. 3e

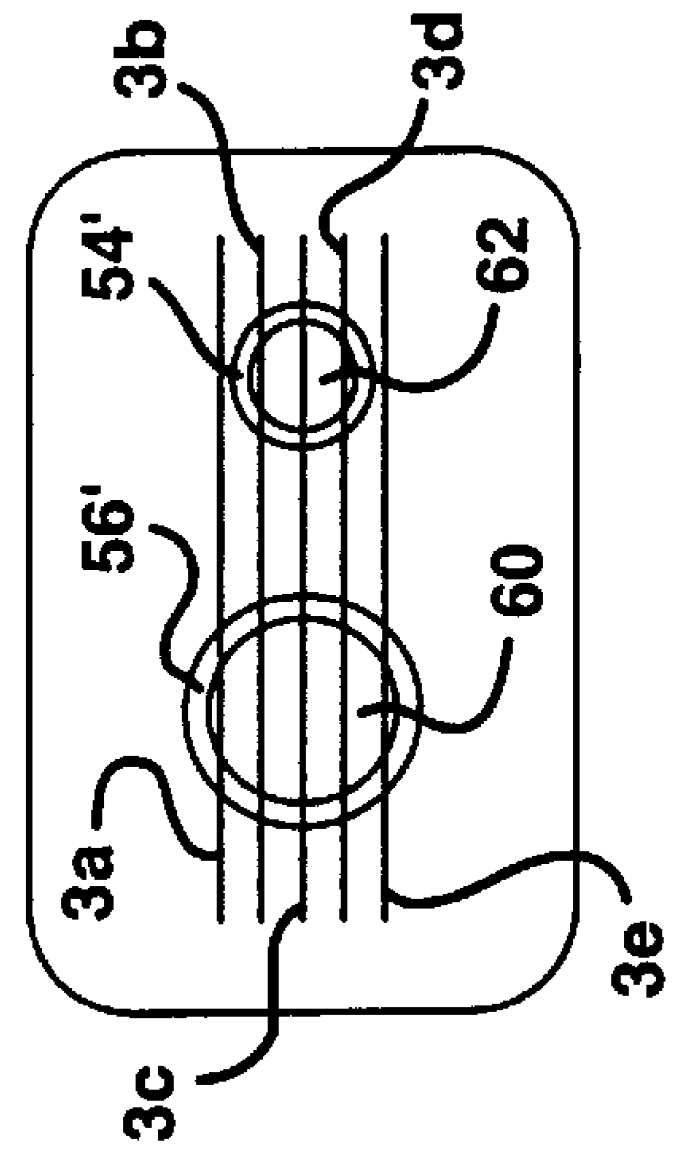


FIG. 4

FIG. 5b

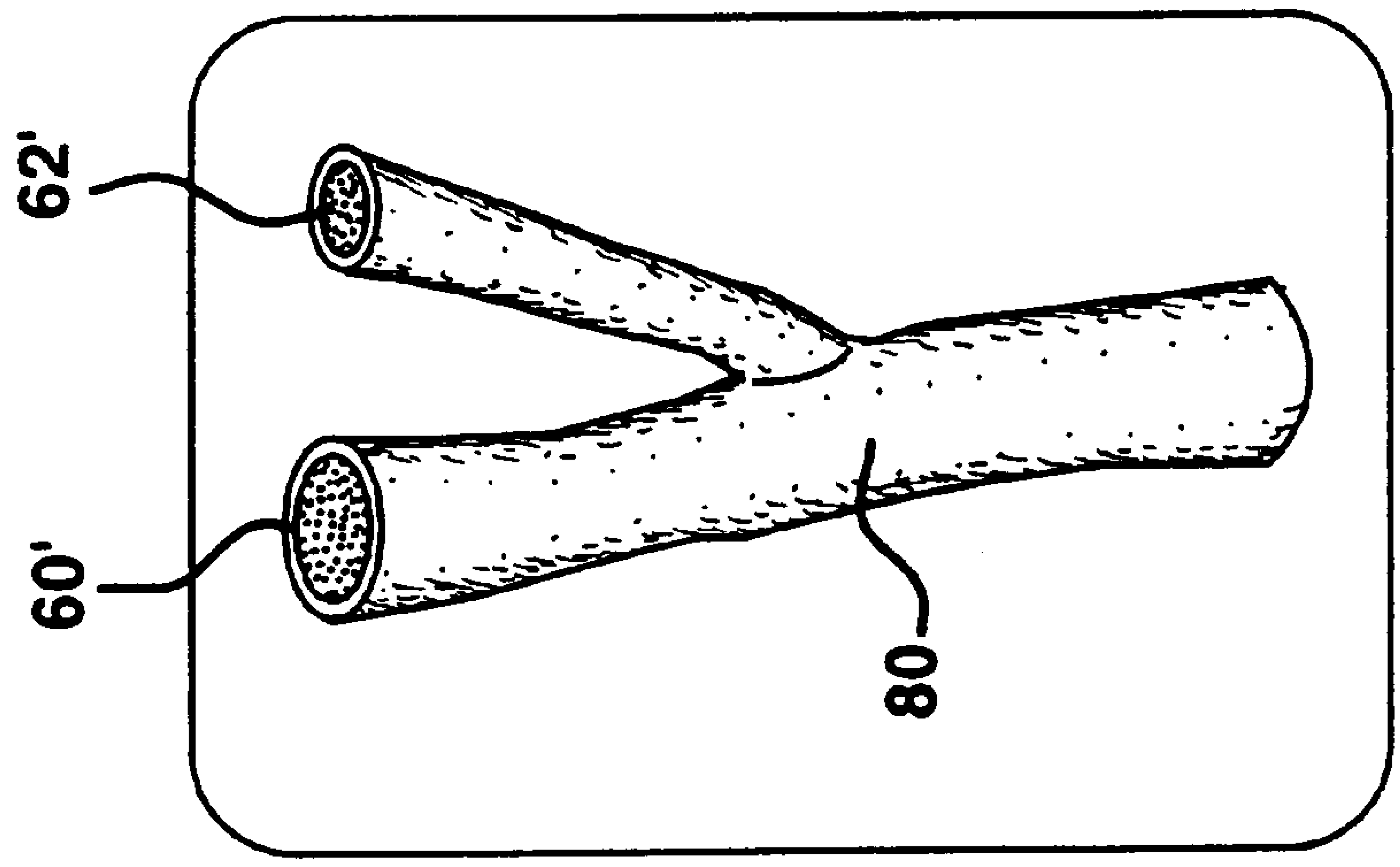


FIG. 5a

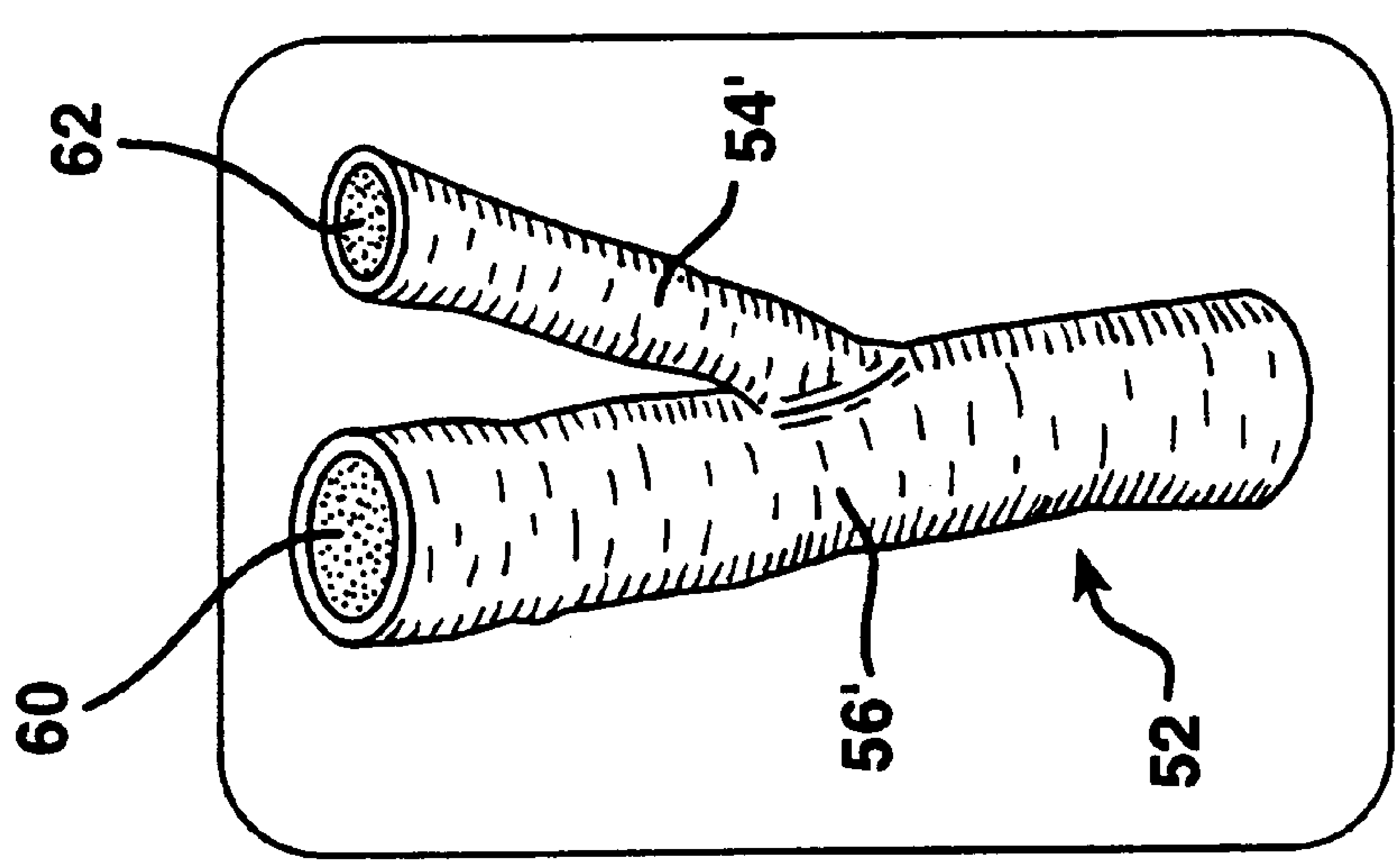


FIG. 6a

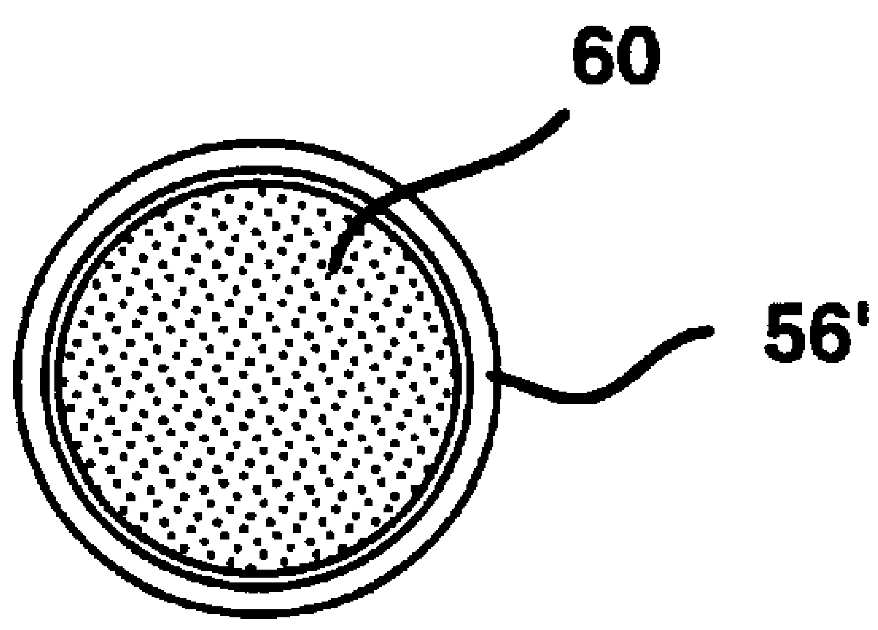


FIG. 6b

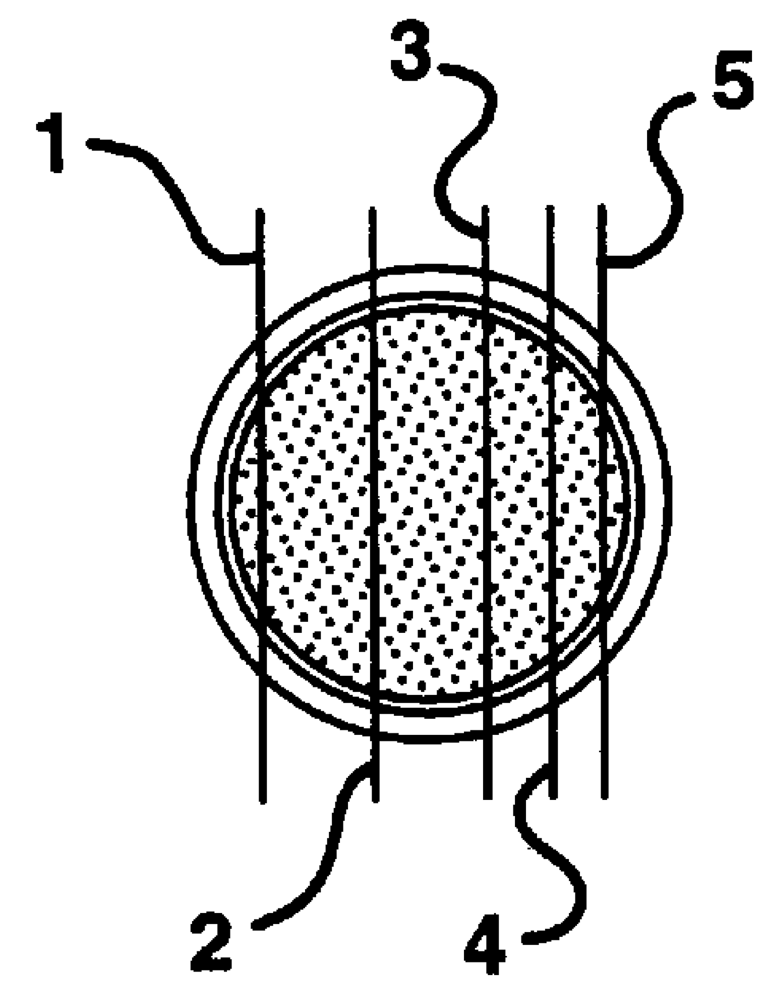


FIG. 6c

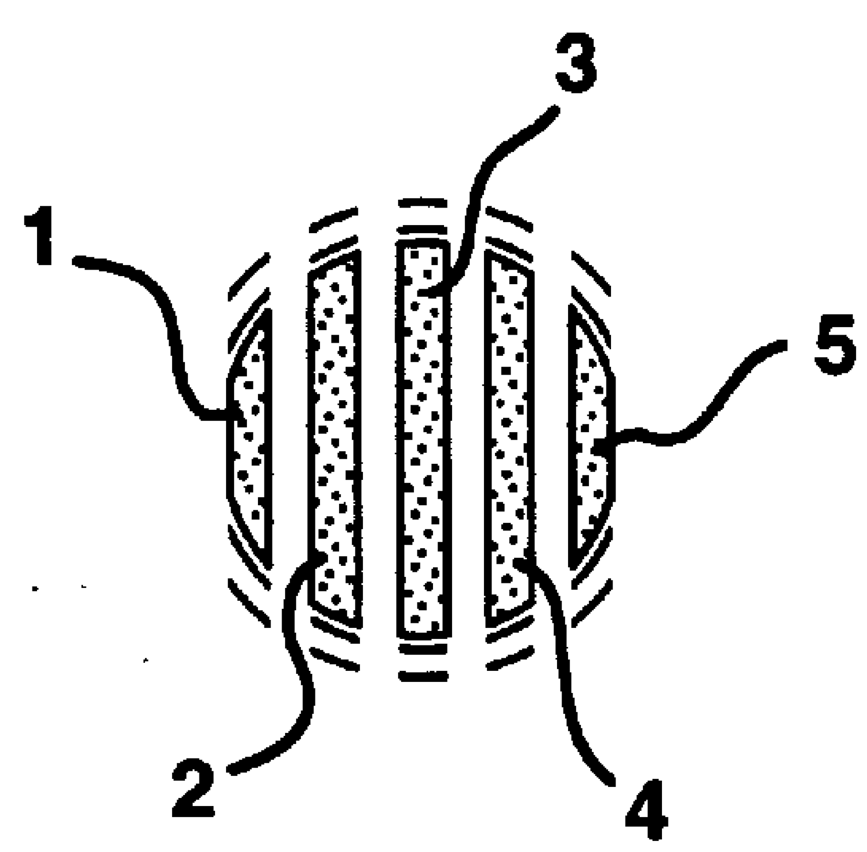


FIG. 6d

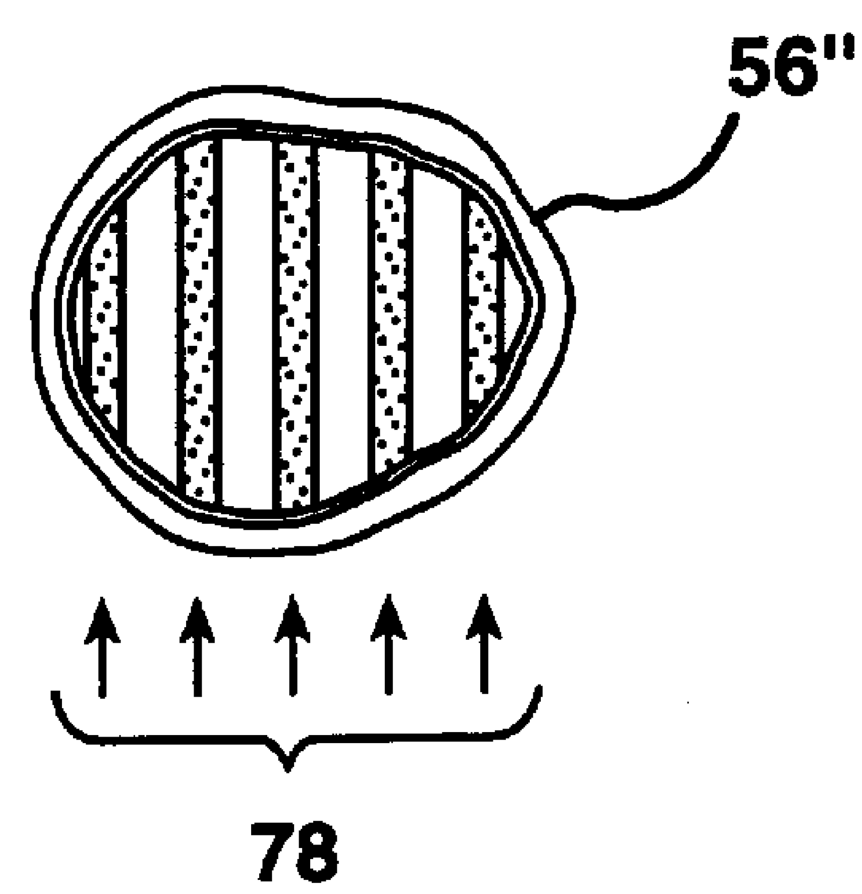


FIG. 7

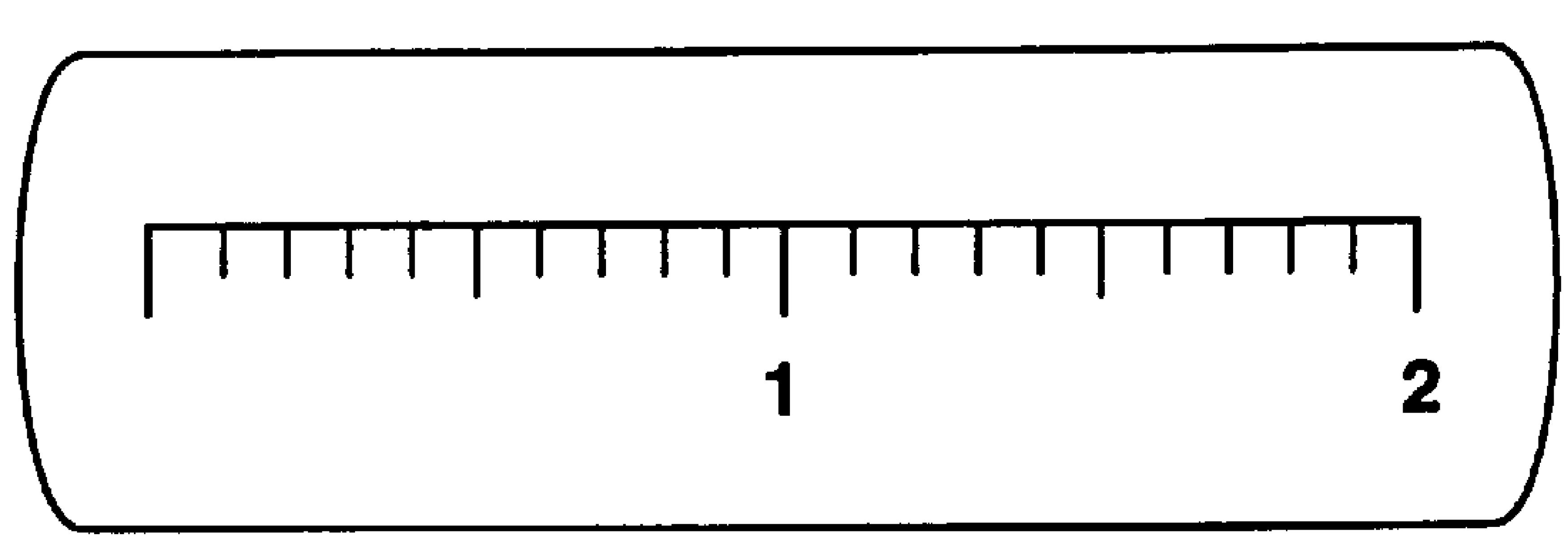
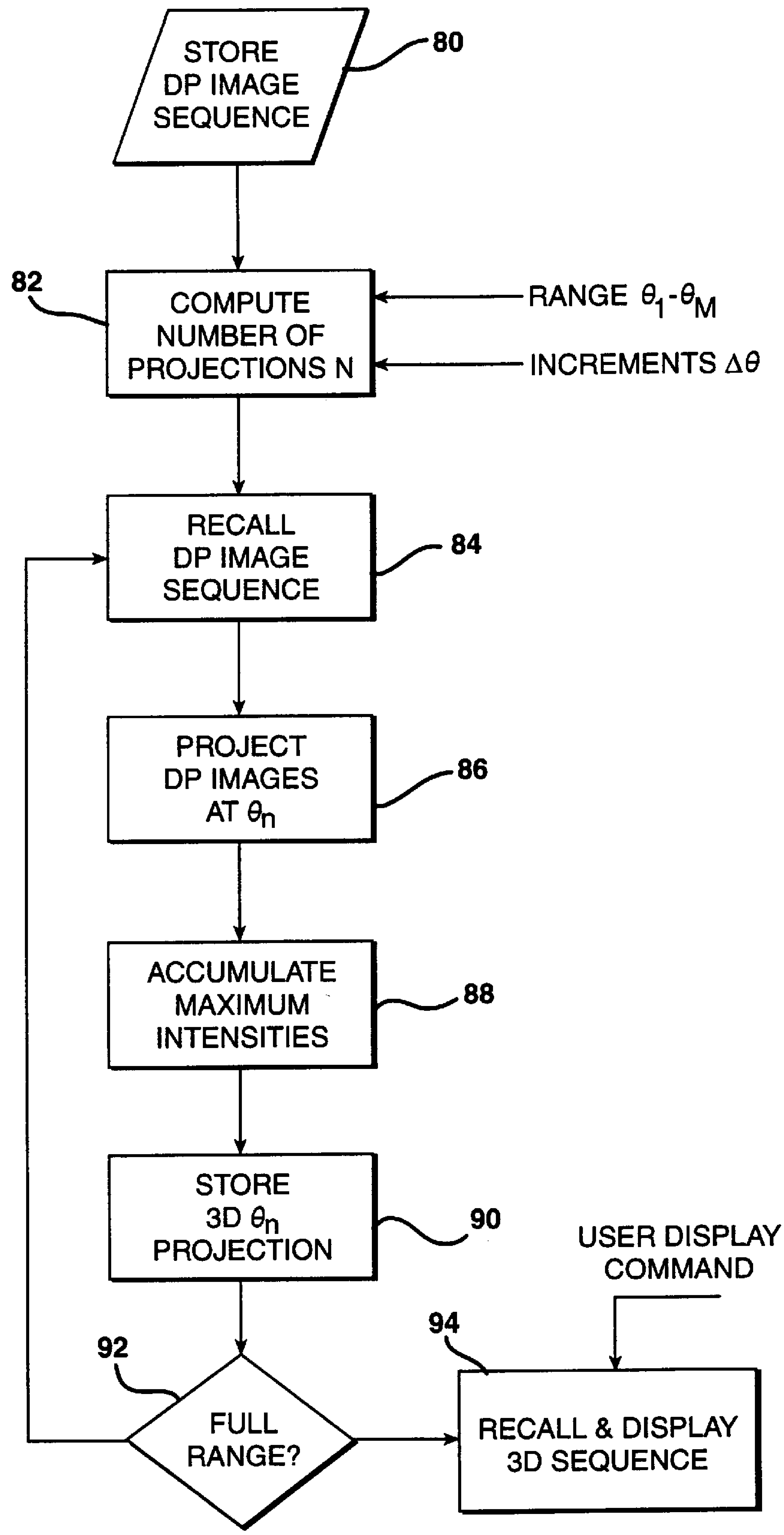


FIG. 8


STORE DP IMAGE SEQUENCE
80
82
COMPUTE NUMBER OF PROJECTIONS N
RANGE θ_1-θ_M
INCREMENTS $\Delta\theta$
RECALL DP IMAGE SEQUENCE
84
PROJECT DP IMAGES AT θ_n
86
ACCUMULATE MAXIMUM INTENSITIES
88
STORE 3D θ_n PROJECTION
90
USER DISPLAY COMMAND
94
92
FULL RANGE?
RECALL & DISPLAY 3D SEQUENCE

ULTRASONIC DIAGNOSTIC SCANNING FOR THREE DIMENSIONAL DISPLAY

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

This invention relates to improvements in ultrasonic diagnostic imaging techniques, and in particular to ultrasonic scanning of the body to acquire Doppler information for presentation in a three dimensional image format.

Various methods and devices have been proposed for ultrasonically scanning a volume within a subject for three dimensional analysis and display. Many of these techniques involve the scanning of a number of spatially adjacent image planes. The ultrasonic information from these associated planes can be analyzed and displayed on the basis of spatial coordinates of the data within a plane, and on the basis of the spatial relationship of each plane to the others. The information can be displayed in a three dimensional image format such as a perspective view of the volume being imaged.

A number of scanning techniques utilizing specially devised scanning devices have been proposed for acquiring these spatially related image planes. The article "Three-Dimensional Reconstruction of Echocardiograms Based On Orthogonal Sections," by S. Tamura et al., Pattern Recognition, vol. 18, no. 2, pp 115–24 (1985) discusses three such devices: a guide rail to guide an ultrasonic probe while acquiring parallel image planes; a jointed arm in which sensors in the arm joints provide spatial coordinates for the transducer; and rotation of a transducer about the cardiac long axis. A rotating transducer probe for the latter purpose is shown and described in "Multidimensional Ultrasonic Imaging for Cardiology," by H. McCann et al., Proceedings of the IEEE, vol. 76, no. 9, pp 1063–73 (Sept. 1988). It would be preferable, however, to be able to acquire multiple image planes for three dimensional presentation without the need for special scanning devices or apparatus.

Ultrasonic images are subject to image artifacts arising from a number of sources such as reverberation, multipath echoes, and coherent wave interference. These artifacts will manifest themselves in various ways in the image which can be broadly described as image clutter. The image clutter becomes particularly troublesome when images are presented in a three dimensional format, as the three dimensional clutter can interfere with and obscure pathology which the clinician is attempting to diagnose. Accordingly it would be desirable to provide ultrasonic image information in a format in which clutter does not significantly impair the pathology being viewed.

In accordance with the principles of the present invention the present inventors have addressed this problem of obscuring clutter through the use of ultrasonic Doppler information signals. Doppler information has been used to image the body in two distinct ways. One Doppler imaging technique is commonly referred to as color Doppler velocity imaging. As is well known, this technique involves the acquisition of Doppler data at different locations called sample volumes over the image plane of an ultrasonic image. The Doppler data is acquired over time and used to estimate the Doppler phase shift or frequency at each discrete sample volume. The Doppler phase shift or frequency corresponds to the velocity of tissue motion or fluid flow in vessels within the body, with the polarity of the shift indicating direction of motion or flow. This information is color coded in accordance with the magnitude of the shift (velocity) and its polarity, and overlaid over a structural image of the tissue in the image plane to define the structure of the moving organs or vessels in which fluids are flowing. The colors in the image thereby provide an indication of the speed of blood flow and its direction in the heart and blood vessels, for instance.

A second Doppler technique is known as color power Doppler. This technique is unconcerned with estimations of the velocity of motion or fluid flow. Rather, it focuses simply on the intensity of the received signals which exhibit a Doppler shift. This Doppler signal intensity can be measured at each sample volume in an image plane and displayed in a color variation. Unlike color Doppler velocity imaging, color power Doppler does not present the problems of directionality determination, aliasing, and low sensitivity which are characteristic of velocity imaging. Color power Doppler simply displays the Doppler signal intensity at a sample volume in a coded color. Like color Doppler velocity imaging, the color power Doppler display is overlaid with a structural B mode image to define the organ or tissue structure in which motion is occurring. Since the value at each sample volume can be averaged over time or based upon a peak value, and is not subject to the constant changes of velocity and direction which are characteristic of the pulsatility of Doppler velocity signals, the color power Doppler display can be presented as a more stable display of motion or flow conditions in the body.

In accordance with the principles of the present invention, a three dimensional ultrasonic display technique is provided which utilizes power Doppler signal information. The present inventors have utilized power Doppler images in an unconventional way, which is in the absence of structural (B mode) information. The present inventors have discovered that utilizing power Doppler information alone in a three dimensional display eliminates the substantial clutter contribution of the structural information signals, eliminates pulsatility variation, provides excellent sensitivity to low energy flow signals, reduces Doppler angle effects, and provides a segmentation of the flow or motion characteristics in the three dimensional image. The present inventors also present a technique for acquiring diagnostic three dimensional ultrasonic images through manual hand scanning of a patient, without the need for specially fabricated scanning mechanisms or devices.

In the drawings:

FIG. **1** is a block diagram of an ultrasonic diagnostic imaging system constructed in accordance with the principles of the present invention;

FIG. **2** illustrates the manual scanning of a bifurcation in the body of a patient;

FIGS. **3**a–**3**e illustrate a sequence of two dimensional Doppler power images acquired from the bifurcation of FIG. **2**;

FIG. **4** illustrates the relation of the image planes of FIGS. **3**a–**3**e to the structure of the bifurcation of FIG. **2**;

FIGS. **5**a and **5**b are a comparison of the bifurcation of FIG. **2** to a three dimensional Doppler power display of the blood flow of the bifurcation;

FIGS. **6**a–**6**d illustrates the three dimensional relationship of manually acquired two dimensional image planes;

FIG. **7** illustrates a scanning aid for manually acquiring uniformly spaced image planes; and

FIG. **8** is a flow chart used to explain the preferred technique for processing Doppler power images for three dimensional display.

Referring first to FIG. **1**, a block diagram of an ultrasonic diagnostic imaging system constructed in accordance with the principles of the present invention is shown. An ultrasonic probe **10** includes a multielement transducer **12** which transmits waves of ultrasonic energy into the body of a patient and receives ultrasonic echoes returning from structures in the body. In the case of ultrasonic wave transmission for Doppler interrogation of the body, it is the echoes returning from moving tissue, blood and other fluids in the body that are of interest. The ultrasonic probe **10** is connected to a transmitter/receiver **14** which alternately pulses individual elements of the transducer to shape and steer an ultrasonic beam, and receives, amplifies and digitizes echo signals received by the transducer elements following each pulse transmission.

The transmitter/receiver **14** is coupled to a beamformer **16** which controls the times of activation of specific elements of the transducer **12** by the transmitter/receiver. This timing enables the transducer **12** to transmit a shaped and focused ultrasound beam in a desired direction. The beamformer **16** also receives the digitized echo signals produced by the transmitter/receiver during echo reception and appropriately delays and sums them to form coherent echo signals.

The echo signals produced by the beamformer **16** are coupled to a B mode processor **30** and an I,Q demodulator **18**. The B mode processor processes the amplitude information of the echo signals on a spatial basis for the formation of a structural image of the tissue in the area of the patient being scanned. The I,Q demodulator **18** demodulates the received echo signals into quadrature components for Doppler processing. The I,Q components are filtered by a wall filter **20** to remove low frequency artifacts stemming from the movement of vessel walls in applications where it is only the motion of flowing fluids such as blood that is of interest. The filtered I,Q components are then applied to a Doppler shift estimation processor **22** and a Doppler power estimation processor **24**.

The Doppler shift estimation processor **22** operates in the conventional manner to estimate a Doppler phase or frequency shift from the I,Q components at each sample volume location of the image field. The Doppler shift estimation processor operates on a number of signal samples resulting from the interrogation of each sample volume location by an ensemble of Doppler interrogation pulses. The sample volume values are applied to a velocity image processor **26** which maps the values to color values for display. The color values are applied to a scan converter and display processor **32** which spatially arranges the color values in the desired image format. The color values are displayed as pixels on a display **40**, wherein each color represents a particular velocity of flow in a particular direction at that pixel location. The color flow velocity information is overlaid with a structural image of the interior of the body utilizing the structural information provided by the B mode processor **30**. This compound image shows both the direction and velocity of blood flow, as well as the structure of the vessels or organs which contain the flowing blood.

In accordance with the principles of the present invention the Doppler system of FIG. **1** also includes a power Doppler imaging capability. The power Doppler components include a Doppler power estimation processor **24** which estimates the Doppler signal power magnitude from the I,Q signal components at each sample volume location using the expression $(I^2+Q^2)^{1/2}$. The Doppler power estimates at each location can be processed and displayed in real time or can be averaged with earlier acquired power estimates for each sample volume location. In a preferred embodiment, each sample volume location is interrogated by a number of pulses and the estimation processor **24** utilizes the signals obtained from all interrogations in the estimations of Dop-

pler power at the sample volume locations. These Doppler power estimates are mapped to display intensity or color values by a power image processor **28**. The display values with their spatial coordinates are stored in separate planar images in an image sequence memory **34** and are also applied to the scan converter and display processor **32** which spatially arranges the Doppler power display values in the desired image format, e.g., sector or rectangular. The two dimensional Doppler power images may then be displayed on a display **40** or recalled from the image sequence memory **34** for three dimensional processing using a peak detector **36** for maximum Doppler power intensity detection as discussed below. User operation of the system of FIG. **1** is effected through various user controls **42** which enable the user to select the type of imaging to be performed, i.e., B mode, color velocity Doppler or Doppler power imaging, and to store and retrieve images from the image sequence memory **34** for three dimensional display, for example.

FIG. **2** illustrates the use of the ultrasonic probe **10** to manually acquire a sequence of image planes for three dimensional display. A portion of the probe cable **11** leading to the transmitter/receiver of the ultrasound system is shown at the top of the probe. The transducer aperture of the probe **10** is in contact with the skin of the patient over the region of the body which is to be scanned. The skin of the patient is represented by a layer **50** in the drawing. In this example the region of the patient being scanned includes a blood vessel bifurcation **52** having a small vessel **54** branching out from a larger vessel **56**. Blood is flowing inside the structural walls of the vessels as indicated at **60** and **62**.

The bifurcation **52** may be scanned by rocking or fanning the probe **10** while it is in contact with the patient. In a preferred technique the probe aperture slides over the skin **50** as indicated by arrow **58** to scan the bifurcation region with a plurality of substantially parallel image planes. One such image plane **64**, here shown as a sector, is seen projecting from the transducer aperture of the probe. The relation of the image plane **64** to the probe is denoted by an image plane marker **13** on the side of the probe case. The marker **13** is in the same plane as the image plane **64**, and denotes the upper left side of the image in its uninverted display orientation.

In accordance with the present invention, the ultrasound system acquires and processes power Doppler information from a plurality of image planes as the probe slides over the bifurcation region of the patient as indicated by the arrow **58**. The duration of such a scan can typically last about ten to twenty seconds, during which time 100 to 200 image planes of power Doppler information are acquired, processed and stored in the image sequence memory **34**. This image information is processed to detect and record the maximum Doppler intensity at a number of different viewing angles over a range of such viewing angles as discussed below.

FIGS. **3**a–**3**e shows a five image plane sequence which illustrates the principles of the power Doppler three dimensional imaging technique of the present invention. The five image planes of the sequence are referenced to the structure of the bifurcation **52** in FIG. **4**, which is a view of the top of the two vessels. FIG. **3**a is a power Doppler image taken along plane **3**a of FIG. **4**, which is seen to intersect the upper edge of the blood flow of the large vessel **56**, just inside the vessel wall **56**'. In FIG. **3**b the image plane intersects a greater cross section **72** of the blood flow of the large vessel **56**, and the edge **74** of the blood flow of the small vessel **54**, just inside the vessel wall **54**' as plane **3**b of FIG. **4** shows. The image plane of FIG. **3**c intersects the centers of both vessel as is seen by plane **3**c in FIG. **4**. In FIG. **3**d the image plane moves down to a lesser cross section of both vessels and the plane **3**e of FIG. **3**e intersects only the peripheral blood flow in the large vessel **56**.

The images of FIGS. **3**a–**3**e are processed and presented together in a three dimensional presentation as illustrated in FIG. **5**b. The three dimensional image is seen to comprise the power Doppler information without any structural image overlay. This is clearly seen by comparing the three dimensional power Doppler image **80** of FIG. **5**b with the similarly scaled rendering of the bifurcation **52** in FIG. **5**a. The rendering of FIG. **5**a is seen to include the structure of the vessel walls **54**' and **56**' which contain flowing blood indicated at **60** and **62**. The power Doppler image **80**, resulting from the Doppler detected movement of the flowing blood, is displayed without any B mode structure of the vessel walls **54**' and **56**'. It has been found that omitting the vessel walls from the three dimensional display does not diminish the effectiveness of the display, as the continuity of the blood flow intensity serves to define the paths in which blood is flowing. In addition, the absence of B mode echos eliminates considerable structural echo clutter from the image. The image is clearly segmented by the flow selectivity, and the smoothly varying stability and sensitivity of the maximum intensity power Doppler information.

FIG. **8** is a flowchart illustrating a preferred technique for processing a sequence of planar Doppler power images for real time three dimensional display. As described above, the Doppler power display values with their spatial coordinates are stored in a sequence of planar images in the image sequence memory **34**, as shown by step **80** in FIG. **8**. The images of FIGS. **3**a–**3**e are illustrative of such a two dimensional image sequence. In step **82** the process receives processing parameters provided by the user controls. One parameter is the range of viewing angles, θ_1–θ_M, over which the three dimensional presentation is to be viewed. The other parameter is the increment $\Delta\theta$ between each viewing angle in the range. For instance the user could input a range of viewing angles of +60° to −60°, referenced to a line of view in a plane which is normal to the plane of the first image in the sequence, and a range increment of 1°. From these inputs the number of three dimensional projections needed is computed in step **82**. In this example **121** projections are needed to display a 120° range span in one degree increments.

The process now begins to form the necessary sequence of 121 maximum intensity projections. In step **84** the planar Doppler power images are recalled from the image sequence memory for sequential processing by the scan converter and display processor **32**. In step **86** each planar image is rotated to one of the viewing angles θ_n, then projected back to the viewing plane. In step **88** the pixels of the projected planar images are accumulated on a maximum intensity basis. Each projected planar image is overlaid over the previously accumulated projected images but in a transposed location in the image plane which is a function of the viewing angle and the interplane spacing: the greater the viewing angle, the greater the transposition displacement from one image to the next. The display pixels chosen from the accumulated images are the maximum intensity pixels taken at each point in the image planes from all of the overlaid pixels accumulated at each point in the image. This effectively presents the maximum intensity of Doppler power seen by the viewer along every viewing line between the viewer and the three dimensional image. In a preferred embodiment the relocation of image points after rotation about the y axis, projection and transposition may be expressed as:

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} x\cos(\theta) \\ y \end{bmatrix} + \begin{bmatrix} z\sin(\theta) \\ 0 \end{bmatrix}$$

and the relocation of image points after rotation about the x axis, projection and transposition may be expressed as:

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} x \\ y\cos(\theta) \end{bmatrix} - \begin{bmatrix} 0 \\ z\sin(\theta) \end{bmatrix}$$

where θ is the angle of rotation, (x, y, z) are the coordinates of a point to be relocated, and (x', y') are the coordinates of a point in the viewing plane after relocation.

After all of the planar images have been rotated, projected, transposed, overlaid, and the maximum intensities at each pixel chosen, the resulting three dimensional image for the viewing angle θ_n is stored in the image sequence memory **34** as a brightness modulated monochrome image in a three dimensional image sequence. In step **92** the process returns to step **84** and proceeds through steps **84**–**92** until the full three dimensional image sequence has been stored in memory. In the present example this is a sequence of **121** three dimensional images over the range of +60° to −60°.

The stored three dimensional sequence is now available for recall and display in step **94** upon command of the user. As the sequence is recalled and displayed in real time, the user sees a three dimensional presentation of the motion or fluid flow occurring in the volumetric region over which the planar images were acquired. The volumetric region is viewed three dimensionally as if the user were moving around the region and viewing the motion or flow from changing viewing angles. In this particular example the user has the impression of moving over a range of viewing angles spanning 120° around the volumetric region. The viewer can sweep back and forth through the sequence, giving the impression of moving around the volumetric region in two directions.

FIGS. **6**a–**6**d illustrate the effects of nonuniform spacing of image planes which can arise from manual image plane scanning. FIG. **6**a is a top view of the large vessel **56**, showing the blood flow **60** surrounded by the vessel wall **56**' for reference. FIG. **6**b shows another sequence of five image planes taken across the vessel but unlike the sequence of FIG. **4**, these image planes are unevenly spaced. Image planes **1** and **2** are seen to be more widely spaced than the closer spacing of image planes **4** and **5**. Such a spacing will result for instance when the probe slides faster when acquiring image planes **1** and **2** and slows down as it approaches the positions of image planes **4** and **5**. This sequence is acquired by manually sliding the probe from left to right at a progressively slower speed across the skin above the vessel **56**.

In a constructed embodiment of the present invention the image planes are assumed to be evenly spaced across the imaged volume and are processed and displayed accordingly. FIG. **6**c shows the five image planes of FIG. **6**b from above when they are evenly spaced for display. The result of this spacing is more readily seen in FIG. **6**d, in which the border of the blood flow and the vessel wall **56**" have been reconnected for ease of illustration. The arrows at **78** illustrate the uniform image plane spacing, which is slightly less than the spacing of image planes **1** and **2** in FIG. **6**b and slightly greater than the spacing of image planes **5** and **6** in that drawing. The effect is to give the cross sectional area of the blood flow a slightly oblong appearance in which the left side of the flow area is compressed and the right side extended in relation to the actual proportions of the blood flow area.

The present inventors have observed that this distortion of the aspect ratio of the three dimensional image does not noticeably detract from the effect of the overall three dimensional display. Even with such aspect distortion the three dimensional image continues to show the relative paths and orientations of blood vessels and the continuity or stenosis of flow in vessels in a manner not achieved by two dimensional presentations. The continuity of flow paths and display effectiveness is enhanced by displaying the Doppler power on the basis of the maximum signal intensity. When the image planes are acquired from a range of acquisition angles the use of the maximum intensity display has the effect of diminishing sensitivity variation resulting from Doppler angle effects. The image planes may be concurrently displayed in the form of a surface rendering or a transparency of the blood flow information, but a preferred presentation is a monochrome display of the varying brightness of the maximum intensity pixels of the combined images of a volumetric region as described above. The flow and perfusion of the blood supply in an organ such as a kidney is more completely displayed with a three dimensional power Doppler image than can be accomplished with a two dimensional presentation. The technique is well suited for assessing the success of organ transplants, for instance.

Simple aids may be provided to improve the accuracy of manual three dimensional scanning if desired. One such aid is shown in FIG. **7**, and comprises a ruler scale printed on a clear strip of surgical tape. The tape is applied to the skin of the patient adjacent to the probe, and the probe is moved along the scale with the marker **13** on the probe used as a reference. Image planes can be acquired at each marker on the scale, or the scale can be traversed in a given time such as twenty seconds. Other aids may also be supplied by the ultrasound system such as audible signals or lights telling the user when to start and stop movement of the probe, and when the moving probe should be passing each marker on the scale.

The imaging techniques of the present invention including particularly that of FIG. **8** can be applied to a sequence of planar images acquired with position sensing of the image planes for display of anatomically precise images. An advantageous Doppler technique for sensing the positions of the image planes and lines in each plane in relation to each other is described in U.S. Pat. No. 5,127,409. When the positions of the image planes or lines are known in relation to each other the three dimensional processor no longer has to assume uniform spacing between two dimensional planes, but can utilize the measured spacing between three dimensional display elements to form more geometrically accurate three dimensional images.

What is claimed is:

1. A method for producing three dimensional ultrasonic images of the interior of a body comprising the steps of:

transmitting ultrasonic waves over a volumetric region of the interior of the body;

receiving ultrasonic Doppler information signals from spatial locations within said region;

processing said ultrasonic Doppler information signals to determine the Doppler power intensity received from said locations within said region; and

displaying said Doppler power intensity on a spatial basis in a three dimensional presentation.

2. The method of claim **1**, wherein said step of processing comprises the step of processing said ultrasonic Doppler information signals to determine the maximum Doppler power intensity received from said locations within said region; and

wherein said step of displaying comprises the step of displaying said maximum Doppler power intensity of said locations on a spatial basis in a three dimensional presentation.

3. The method of claim **2**, wherein said step of transmitting comprises the step of transmitting ultrasonic waves over a series of planar regions of a volumetric region of the interior of the body; and

wherein said step of receiving comprises the step of receiving ultrasonic Doppler information signals from spatial locations within said planar regions.

4. The method of claim **3**, wherein said step of processing comprises the step of processing said ultrasonic Doppler information signals in spatially related image planes to determine the Doppler power intensity received from said locations within each of said image planes; and

wherein the step of displaying comprises the step of concurrently displaying said Doppler power intensity of a plurality of said image planes on a spatial basis in a three dimensional presentation.

5. The method of claim **4**, further comprising the step of identifying the maximum Doppler power intensity at each point in a combination of said spatially related image planes; and

wherein the step of displaying comprises the step of displaying said identified maximum Doppler power intensities on a spatial basis in a three dimensional display.

6. The method of claim **1**, wherein said step of displaying comprises the step of displaying said Doppler power intensity on a spatial basis in the absence of structural echo information signals in a three dimensional presentation.

7. **[**The method of claim **1**,**]** *A method for producing three dimensional ultrasonic images of the interior of a body comprising the steps of:*

transmitting ultrasonic waves over a volumetric region of the interior of the body;

receiving ultrasonic Doppler information signals from spatial locations within said region;

processing said ultrasonic Doppler information signals to determine the Doppler power intensity received from said locations within said region; and

displaying said Doppler power intensity on a spatial basis in a three dimensional presentation,

further comprising the step of providing said transmitting and receiving steps by manually moving an ultrasonic transducer probe which is in contact with said body.

8. An ultrasonic diagnostic imaging system which is capable of providing three dimensional presentations of the interior of a body comprising:

an ultrasonic transducer probe for transmitting ultrasonic waves over a volumetric region of the interior of the body and for receiving ultrasonic Doppler information signals returned from spatial locations within said region;

a power Doppler processor responsive to said ultrasonic Doppler information signals for producing Doppler power intensity signals corresponding to said locations within said region;

an image processor for processing said Doppler power intensity signals for display in a three dimensional image presentation; and a display coupled to said image processor which displays said three dimensional image presentation.

9. The ultrasonic diagnostic imaging system of claim **8**, wherein said image processor comprises means responsive to said Doppler power intensity signals for producing a maximum Doppler power intensity image of said region.

10. The ultrasonic diagnostic imaging system of claim **9**, wherein said ultrasonic transducer probe comprises means for transmitting ultrasonic waves over a series of image planes of a volumetric region of the interior of the body and for receiving ultrasonic Doppler information signals returned from spatial locations within said image planes of said region.

11. The ultrasonic diagnostic imaging system of claim **10**, wherein said image processor further comprises means for processing said Doppler power intensity signals in spatially related image planes to determine the Doppler power intensity corresponding to locations within each of said image planes; and

wherein said display further comprises means for concurrently displaying said Doppler power intensity of a plurality of said image planes on a spatial basis in a three dimensional presentation.

12. The ultrasonic diagnostic imaging system of claim **11**, further comprising a peak detector responsive to the Doppler power intensity determinations corresponding to locations within each of said image planes for identifying the maximum Doppler power intensity at points in a combination of a plurality of image planes; and

wherein said display comprises means for displaying maximum Doppler power intensity images in the absence of concurrent display of tissue structure.

13. The ultrasonic diagnostic imaging system of claim **8**, wherein said image processor further comprises means for processing said Doppler power intensity signals for display in the absence of tissue structure information signals in a three dimensional image presentation.

14. The ultrasonic diagnostic imaging system of claim **13**, further comprising a peak detector responsive to said Doppler power intensity signals for identifying the maximum Doppler power intensity corresponding to said locations within said image planes.

15. The ultrasonic diagnostic imaging system of claim **14**, wherein said ultrasonic transducer probe comprises a manual scanner which is manually moved in relation to said volumetric region to scan a sequence of spatially related image planes in said region.

16. An ultrasonic diagnostic imaging system which is capable of providing three dimensional presentations of a region of a body comprising:

an ultrasonic transducer probe for transmitting ultrasonic waves over a sequence of image planes of said region of the body and for receiving ultrasonic Doppler information signals returned from spatial locations within said image planes while said probe is manually incremented positionally in relation to said region;

a power Doppler processor responsive to said ultrasonic Doppler information signals for estimating the Doppler power corresponding to said locations within said image planes;

an image processor for processing said Doppler power estimates to produce a maximum Doppler power image for display in a three dimensional image presentation in the absence of non Doppler signal information; and

a display responsive to the production of maximum Doppler power images which displays a sequence of

said maximum Doppler power images in a three dimensional image presentation in the absence of a structural display of tissue.

17. The ultrasonic diagnostic imaging system of claim **16**, wherein said image processor comprises means for accumulating said estimates of Doppler power of a plurality of said image planes to form a three dimensional display image of the maximum Doppler power intensity as seen by a viewer from a given viewing perspective.

18. The ultrasonic diagnostic imaging system of claim **17**, further comprising an image sequence memory for storing said estimates of Doppler power in corresponding images and for storing a sequence maximum Doppler power images.

19. A method for producing three dimensional ultrasonic images of the interior of a body comprising the steps of:

transmitting ultrasonic waves over a volumetric region of the interior of the body;

receiving ultrasonic information signals due to motion or flow from spatial locations within said region;

processing said ultrasonic information signals to determine locations within said region where motion or flow is present; and

displaying said motion or flow on a spatial basis in a three dimensional presentation which does not distinguish the direction of said motion or flow.

20. The method of claim 19, wherein said ultrasonic information signals comprise Doppler information signals.

21. The method of claim 19 or 20, wherein said motion or flow is the motion or flow of blood, and wherein said spatial locations comprise the interior of blood vessels.

22. A method for producing three dimensional ultrasonic images of the interior of a body comprising the steps of:

transmitting ultrasonic waves over a volumetric region of the interior of the body;

receiving ultrasonic Doppler information signals from spatial locations within said region;

processing said ultrasonic Doppler information signals to determine magnitude signals of motion or flow within said region; and

displaying, in response to said magnitude signals, locations of motion or flow within said region without regard to motion or flow directionality on a spatial basis in a three dimensional presentation.

23. The method of claim 22, wherein said displaying step displays said magnitude signals without directional polarity on a spatial basis in a three dimensional presentation.

24. The method of claim 22 or 23, wherein said ultrasonic Doppler information signals result from the flow of blood within the body, and wherein said three dimensional presentation is ambiguous as to the direction of said flow of blood.

25. A method for producing three dimensional ultrasonic images of the interior of a body comprising the steps of:

transmitting ultrasonic waves over a volumetric region of the interior of the body;

receiving ultrasonic Doppler information signals due to changing directional motion or flow from spatial locations within said region;

processing said ultrasonic Doppler information signals to determine magnitude signals relating to spatial locations within said region where motion or flow is present; and

displaying the locations of said motion or flow on a spatial basis in a three dimensional presentation without regard to the direction of motion or flow.

26. The method of claim 25, wherein the direction of said motion or flow may be represented by the sign or polarity of a Doppler signal,

wherein said three dimensional presentation is ambiguous as to said sign or polarity.

27. The method of claim 25, wherein magnitude signals corresponding to different directions of motion or flow are displayed on a common basis.

28. An ultrasonic diagnostic imaging system which is capable of providing three dimensional presentations of the interior of a body comprising:

an ultrasonic transducer probe for transmitting ultrasonic waves over a volumetric region of the interior of the body and for receiving ultrasonic information signals returned from spatial locations within said region as the probe is free hand scanned over said region;

an image processor for processing said ultrasonic information signals for display in a three dimensional image presentation; and

a display coupled to said image processor which displays said three dimensional image presentation.

29. An ultrasonic diagnostic imaging system which is capable of providing three dimensional presentations of the interior of a body comprising:

an ultrasonic transducer probe for free hand image plane scanning of a volumetric region of the interior of the body and for receiving ultrasonic information signals returned from spatial locations within said region during said free hand image plane scanning;

an image processor for processing said ultrasonic information signals for display in a three dimensional image presentation; and

a display coupled to said image processor which displays said three dimensional image presentation.

30. The ultrasonic diagnostic imaging system of claim 29, wherein said image processor processes said ultrasonic information signals without quantification of interplane spacing.

31. The ultrasonic diagnostic imaging system of claim 30, wherein said image processor is operated on the basis of uniform interplane spacing.

32. The ultrasonic diagnostic imaging system of claim 29, wherein said probe provides said ultrasonic information signals to said image processor without position sensing of image planes.

33. An ultrasonic diagnostic imaging system which is capable of providing three dimensional presentations of the interior of a body comprising:

an ultrasonic transducer probe which is free hand scanned to sweep transmitted ultrasonic waves over a volumetric region of the interior of the body and for receiving ultrasonic information signals returned from spatial locations within said region;

an image processor for processing said ultrasonic information signals for display in a three dimensional image presentation; and

a display coupled to said image processor which displays said three dimensional image presentation.

34. The ultrasonic diagnostic imaging system of claim 28, 29, or 33, wherein said image processor further comprises a Doppler processor; and wherein said display displays the location of motion or flow in said region in a three dimensional image presentation.

35. A method for producing three dimensional ultrasonic images of the interior of a body comprising the steps of:

transmitting ultrasonic waves over a volumetric region of the interior of the body;

receiving ultrasonic information signals due to motion or flow from spatial locations within said region;

processing said ultrasonic information signals to determine locations within said region where motion or flow is present, which does not distinguish the direction of motion or flow; and

displaying said motion or flow on a spatial basis in a three dimensional presentation in the absence of adjacent B mode structure.

36. The method of claim 35, wherein said processing step comprises Doppler processing said ultrasonic information signals to determine locations within said region where motion or flow is present.

37. An ultrasonic diagnostic imaging system which is capable of providing three dimensional presentations of the interior of a body comprising:

an ultrasonic transducer probe for transmitting ultrasonic waves over a volumetric region of the interior of the body and for receiving ultrasonic information signals returned from motion or flow at spatial locations within said region;

a signal processor for processing said ultrasonic information signals to determine locations within said region where motion or flow is present; and

a display coupled to signal processor for displaying said locations where motion or flow is present on a spatial basis in a three dimensional image presentation which does not distinguish the direction of said motion or flow.

38. The ultrasonic diagnostic imaging system of claim 37, wherein said signal processor comprises a Doppler signal processor.

39. The ultrasonic diagnostic imaging system of claim 38, wherein said motion or flow is bloodflow.

40. An ultrasonic diagnostic imaging system which is capable of providing three dimensional presentations of the interior of a body comprising:

an ultrasonic transducer probe for transmitting ultrasonic waves over a volumetric region of the interior of the body and for receiving Doppler information signals returned from motion or flow at spatial locations within said region;

a signal processor for Doppler processing said Doppler information signals to develop magnitude signals relating to locations within said region where motion or flow is present; and

a display responsive to said magnitude signals for displaying said locations where motion or flow is present on a spatial basis without regard to motion or flow directionality in a three dimensional image presentation.

41. The ultrasonic diagnostic imaging system of claim 40, wherein said Doppler information signals are returned from flowing blood, and wherein said three dimensional image presentation is ambiguous as to the direction of said bloodflow.

42. A method for producing three dimensional ultrasonic images of the interior of a body by free hand scanning with an ultrasound probe, comprising the steps of:

transmitting ultrasonic waves over a volumetric region of the interior of the body and receiving ultrasonic information signals from spatial locations within said region while free hand scanning said region with an ultrasound probe;

processing said ultrasonic information signals for display in a three dimensional image presentation; and

displaying a three dimensional presentation of said ultrasonic information signals.

43. The method of claim 42, wherein said ultrasonic information signals comprise Doppler information signals; and wherein said processing step comprises Doppler processing said information signals.

44. The method of claim 43, wherein said displaying step comprises displaying locations in said region where motion or flow is present in a three dimensional image presentation.

45. A method for producing three dimensional ultrasonic images of the interior of a body by free hand scanning with an ultrasound probe, comprising the steps of:

transmitting ultrasonic waves over a volumetric region of the interior of the body and receiving ultrasonic information signals from spatial locations within said region during free hand image plane scanning with an ultrasound probe;

processing said ultrasonic information signals for display in a three dimensional image presentation; and

displaying a three dimensional presentation of said ultrasonic information signals.

46. The method of claim 45, wherein said processing step comprises processing ultrasonic planar image signals for display in a three dimensional image presentation without quantification of interplane spacing.

47. The method of claim 45, wherein said processing step comprises processing ultrasonic planar image signals for display in a three dimensional image presentation on the basis of assumed uniform interplane spacing.

48. The method of claim 45, wherein said manual image plane scanning is performed without position sensing of image planes.

49. An ultrasonic diagnostic imaging system which is capable of providing three dimensional presentations of the interior of a body comprising:

an ultrasound probe which transmits ultrasonic waves over a volumetric region of the interior of the body and receives ultrasonic information signals due to motion or flow from spatial locations within said region;

a processor coupled to receive said ultrasonic information signals which determines locations within said region where motion or flow is present which does not distinguish the direction of motion or flow; and

a display for displaying locations where said motion or flow is present on a spatial basis in a three dimensional presentation in the absence of adjacent B mode structure.

50. The ultrasonic diagnostic imaging system of claim 49, wherein said processor comprises a Doppler processor.

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