US 20080262356A1

(19) **United States**

(12) **Patent Application Publication**
Chalana et al.

(10) **Pub. No.: US 2008/0262356 A1**

(43) **Pub. Date: Oct. 23, 2008**

(54) **SYSTEMS AND METHODS FOR ULTRASOUND IMAGING USING AN INERTIAL REFERENCE UNIT**

(76) Inventors: **Vikram Chalana**, Mill Creek, WA (US); **Gerald McMorrow**, Kirkland, WA (US); **Jongtae Yuk**, Redmond, WA (US)

Correspondence Address:
BLACK LOWE & GRAHAM, PLLC
701 FIFTH AVENUE, SUITE 4800
SEATTLE, WA 98104 (US)

(21) Appl. No.: **11/925,905**

(22) Filed: **Oct. 27, 2007**

Related U.S. Application Data

(63) Continuation-in-part of application No. 11/222,360, filed on Sep. 8, 2005, which is a continuation-in-part of application No. 11/119,355, filed on Apr. 29, 2005, which is a continuation-in-part of application No. 10/701,955, filed on Nov. 5, 2003, now Pat. No. 7,087,022, which is a continuation-in-part of application No. 10/443,126, filed on May 20, 2003, now Pat. No. 7,041,059, said application No. 11/222,360 is a continuation-in-part of application No. 11/061,867, filed on Feb. 17, 2005, which is a continuation-in-part of application No. 10/704,966, filed on Nov. 12, 2003, now Pat. No. 6,803,308, which is a continuation-in-part of application No. PCT/US03/24368, filed on Aug. 1, 2003, said application No. 11/222,360 is a continuation-in-part of application No. PCT/US03/14785, filed on May 9, 2003, which is a continuation of application No. 10/165,556, filed on Jun. 7, 2002, now Pat. No. 6,676,605, said application No. 11/222,360 is a continuation-in-part of application No. 10/633,186, filed on Jul. 31, 2003, now Pat. No. 7,004,904.

(60) Provisional application No. 60/609,184, filed on Sep. 10, 2004, provisional application No. 60/608,426, filed on Sep. 9, 2004, provisional application No. 60/621,349, filed on Oct. 22, 2004, provisional application No. 60/423,881, filed on Nov. 5, 2002, provisional application No. 60/400,624, filed on Aug. 2, 2002, provisional application No. 60/423,881, filed on Nov. 5, 2002, provisional application No. 60/400,624, filed on Aug. 2, 2002.

(30) **Foreign Application Priority Data**

Dec. 24, 2002 (KR) 10-2002-0083525

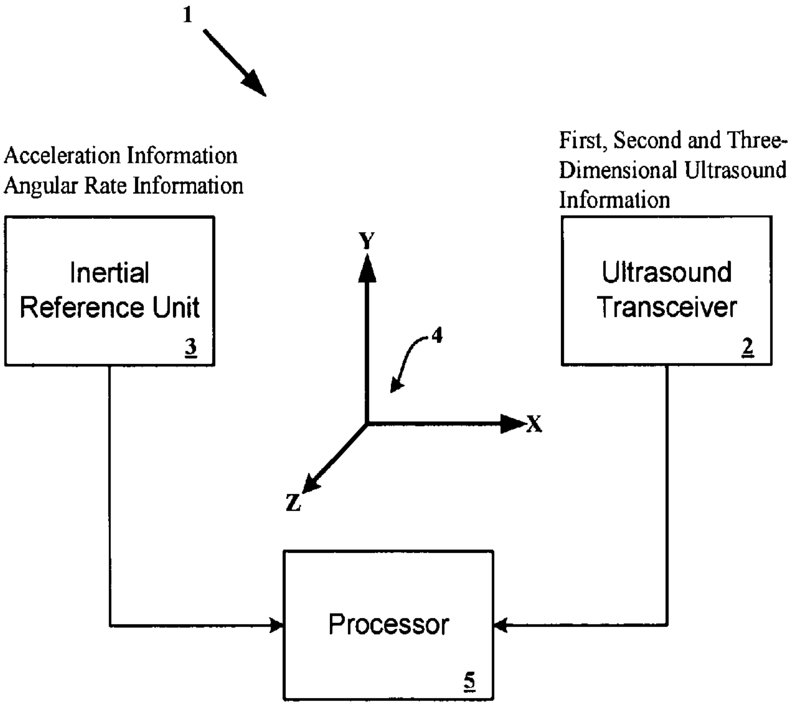
Publication Classification

(51) **Int. Cl.**
A61B 8/13 (2006.01)

(52) **U.S. Cl.** **600/447**

(57) **ABSTRACT**

Systems and methods for ultrasound imaging using an inertial reference unit are disclosed. In one embodiment, an ultrasound imaging system includes an ultrasound unit configured to ultrasonically scan at least one plane within a region of interest in a subject and generate imaging information from the scan. An inertial reference unit is provided that detects relative positions of the ultrasound unit as the ultrasound unit scans a plurality of plane. A processing unit is configured to receive the imaging information and the corresponding detected position and is operable to generate images of the region of interest.



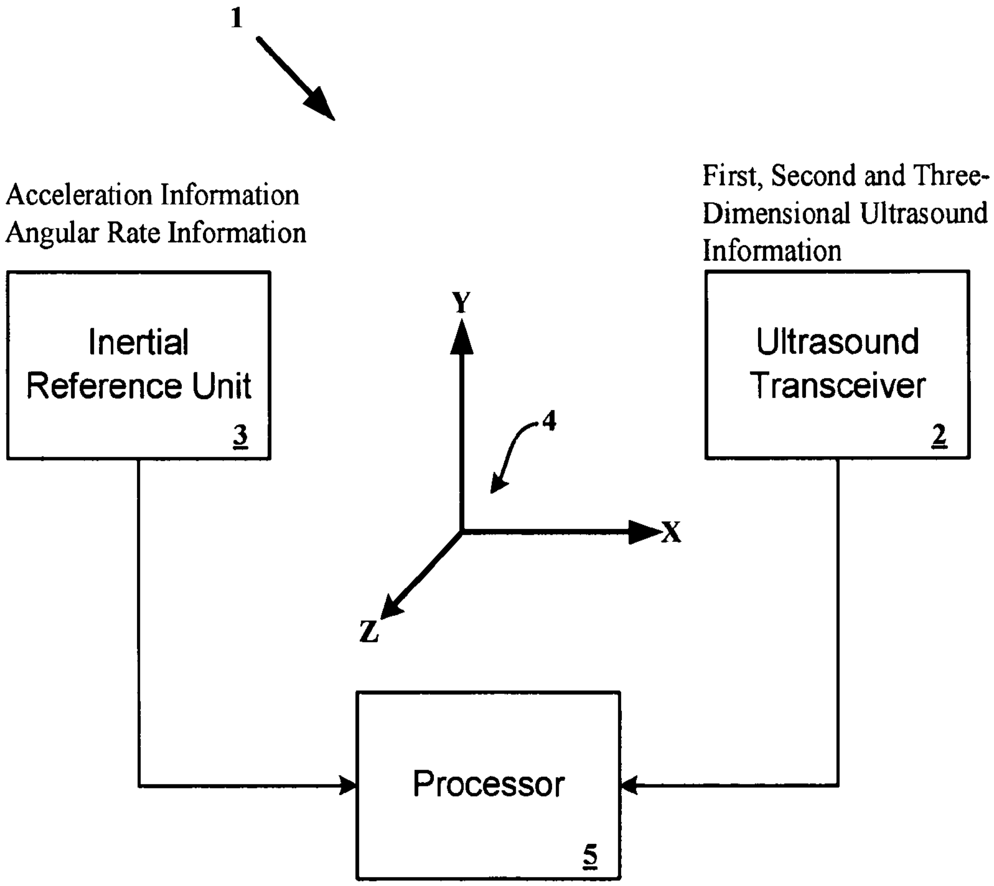

1
Acceleration Information
Angular Rate Information
First, Second and Three-Dimensional Ultrasound Information
Inertial Reference Unit
3
Y
4
X
Z
Ultrasound Transceiver
2
Processor
5

Fig. 1

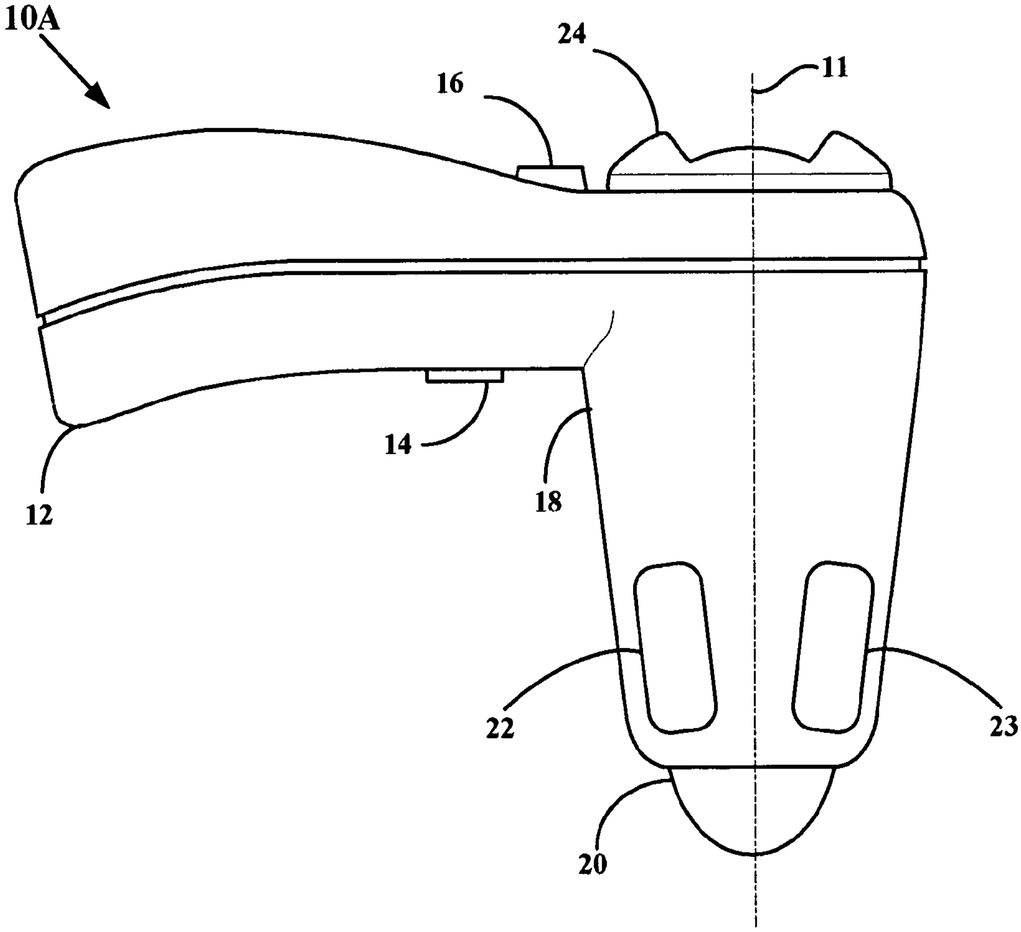


Fig. 1A

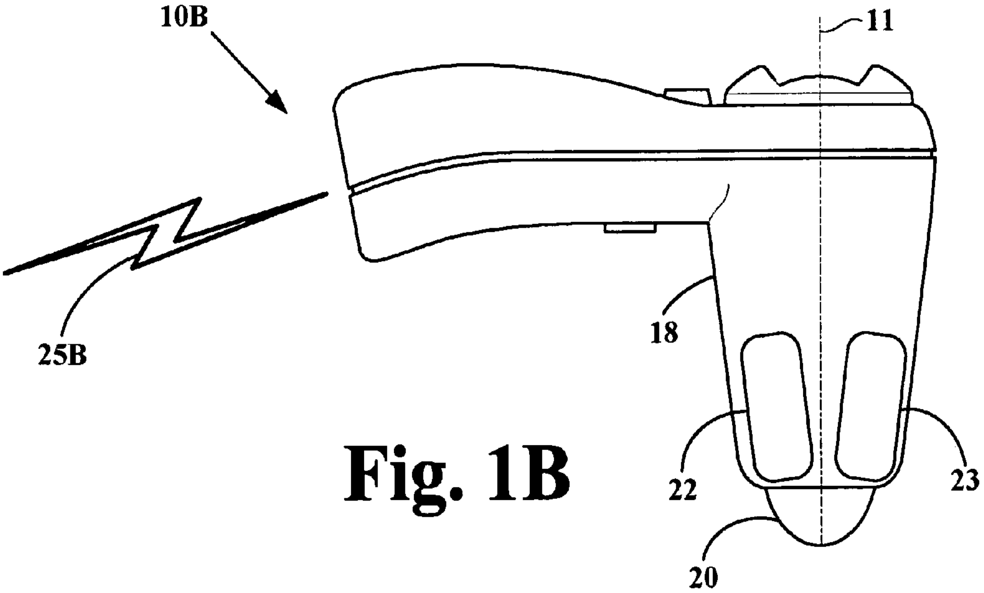


Fig. 1B

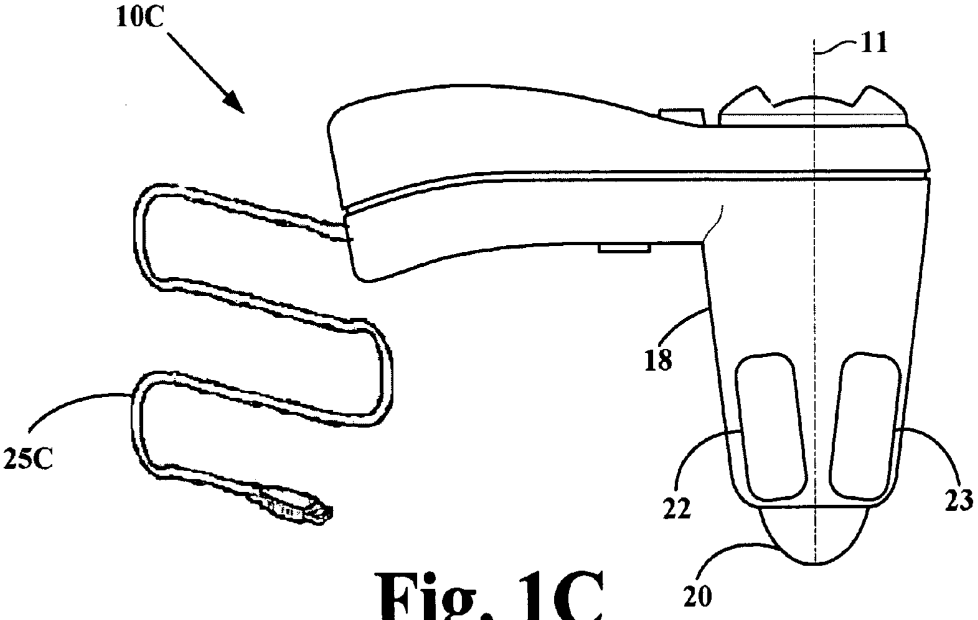


Fig. 1C

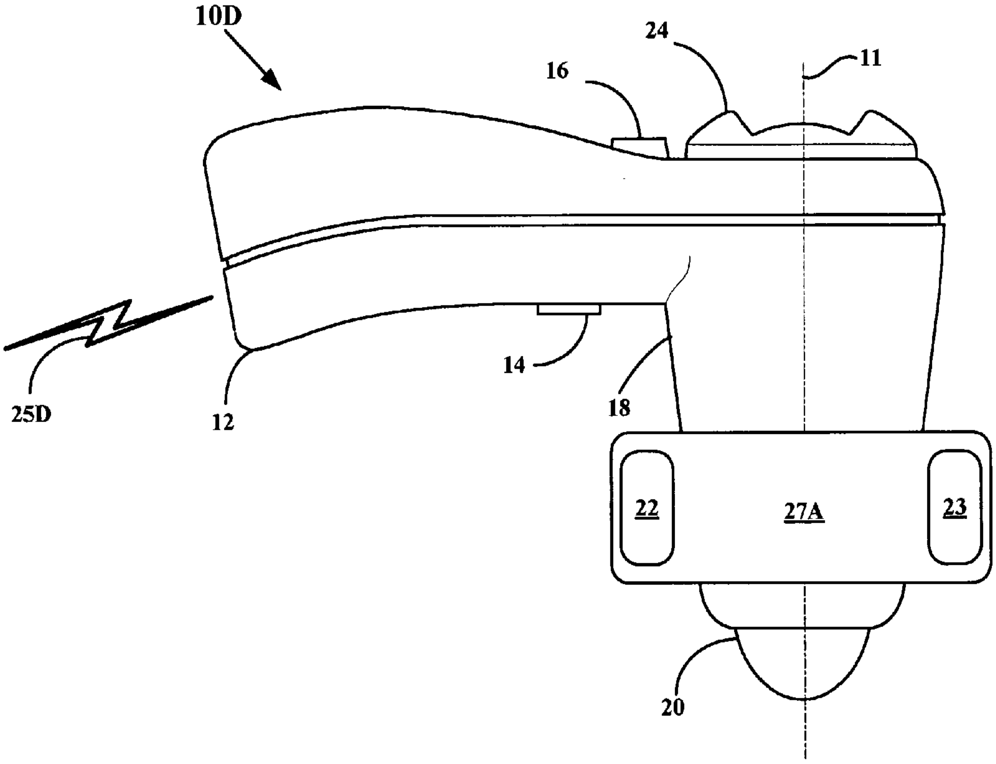


Fig. 1D

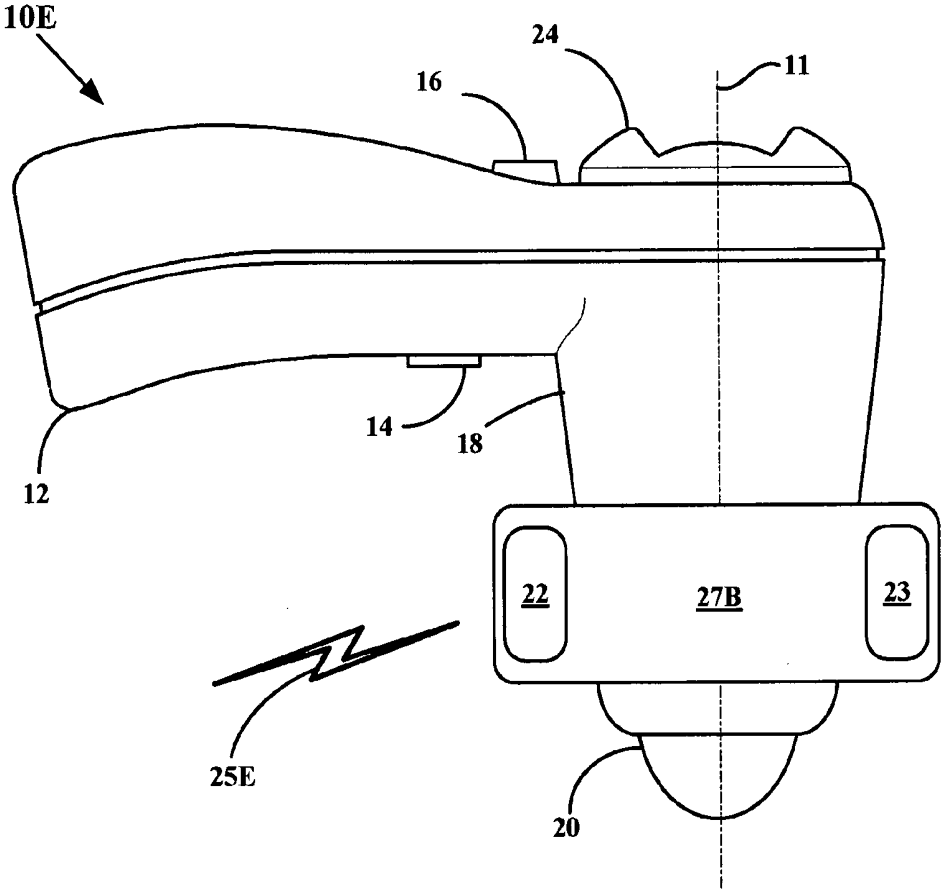


Fig. 1E

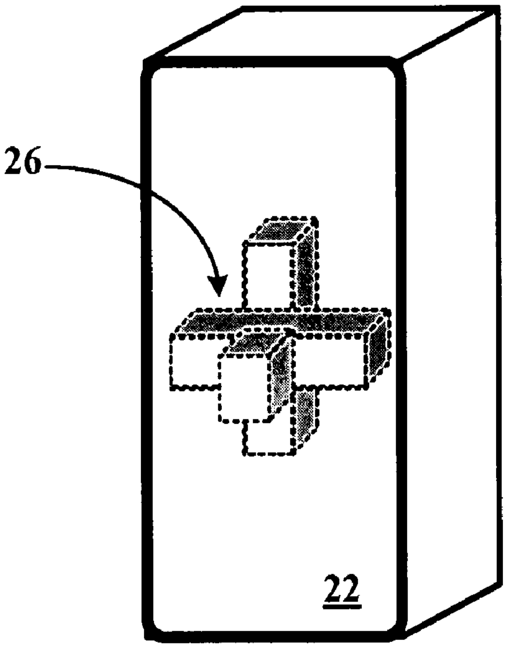


Fig. 2A

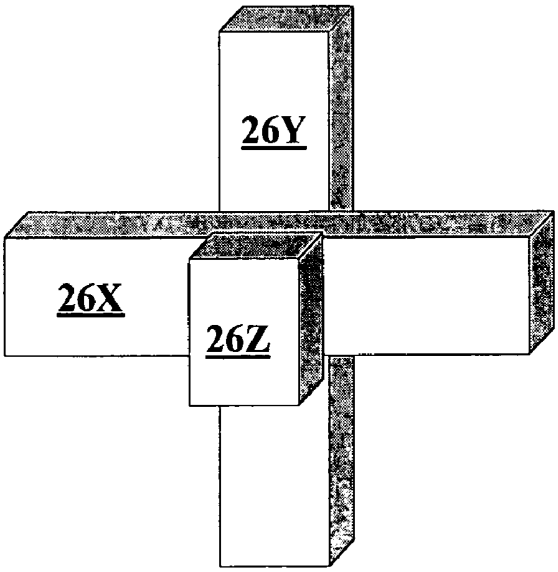


Fig. 2B

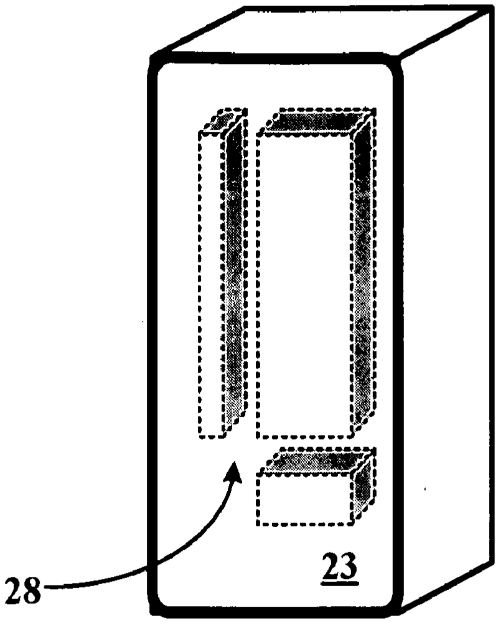


Fig. 3A

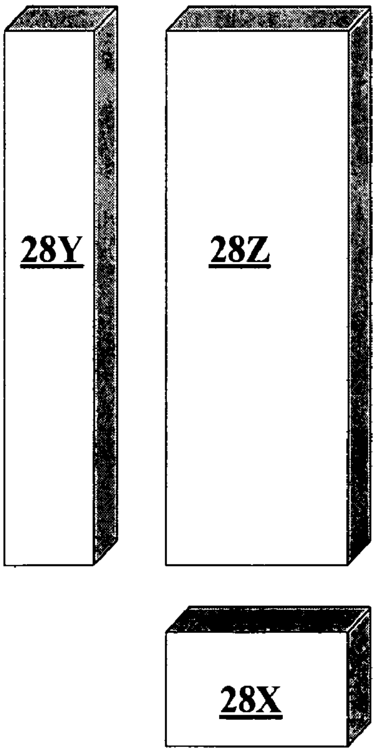


Fig. 3B

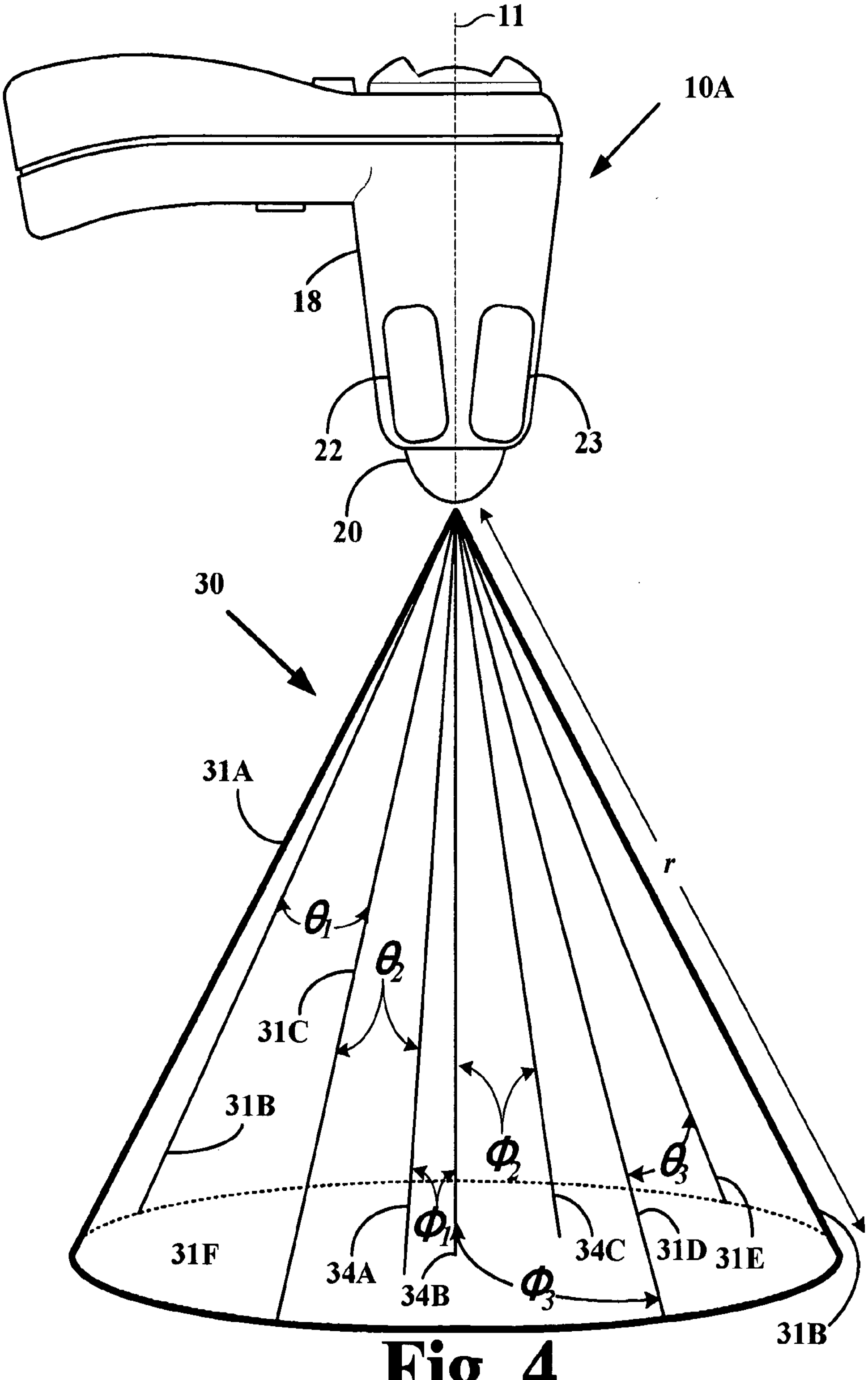

11
10A
18
22
23
20
30
31A
θ_1
θ_2
31C
31B
Φ_2
θ_3
r
Φ_1
31F
34A
34B
Φ_3
34C
31D
31E
31B

Fig. 4

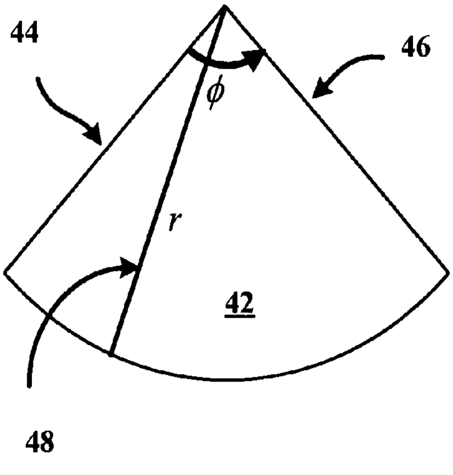


Fig. 5B

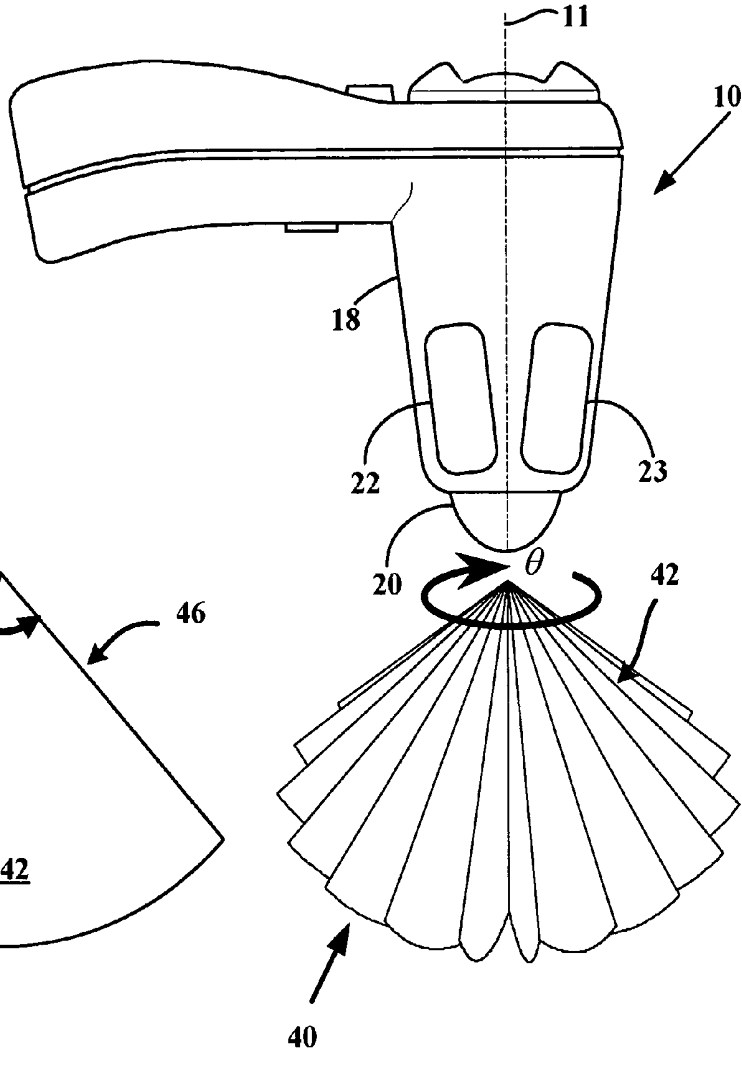


Fig. 5A

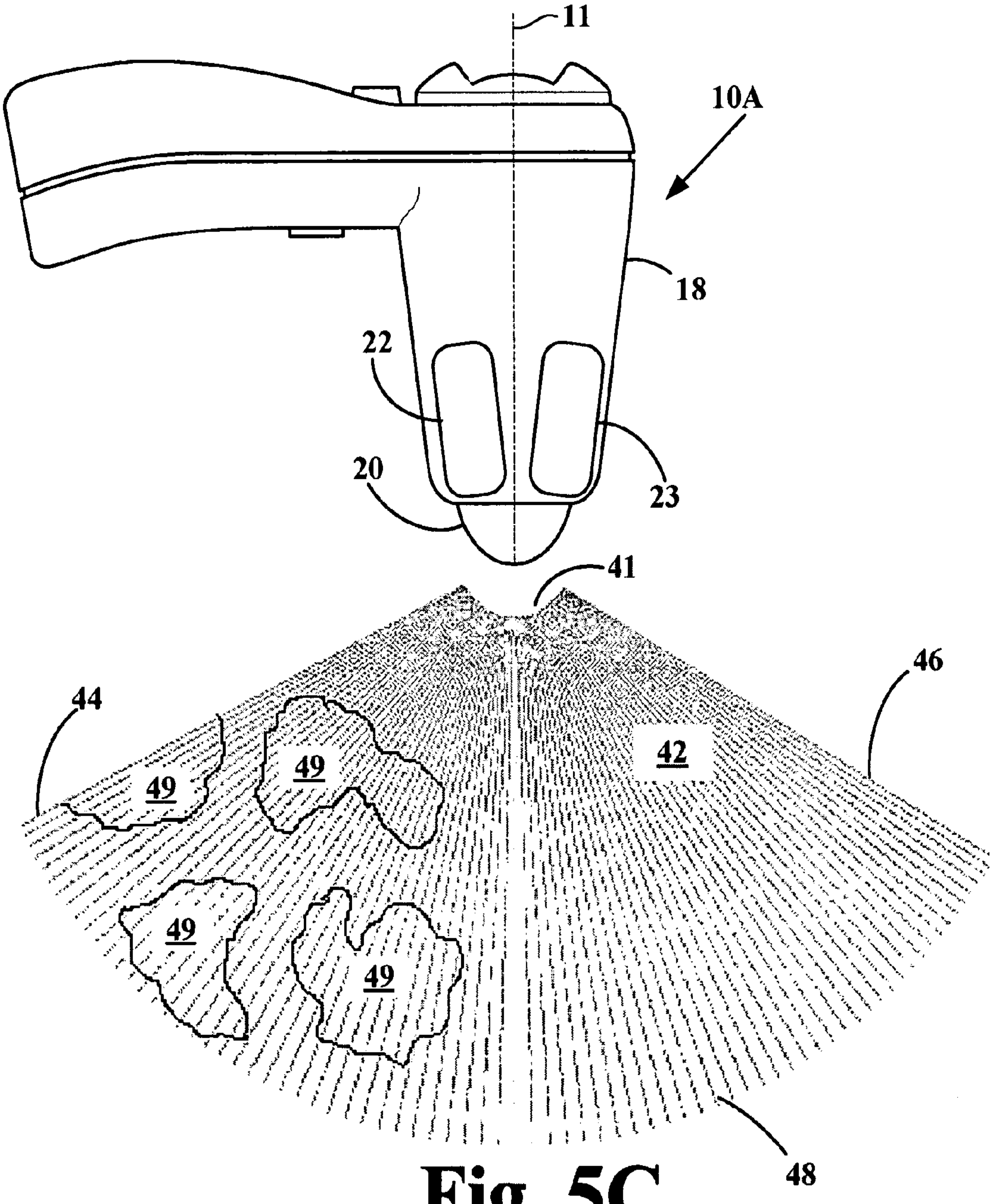


Fig. 5C

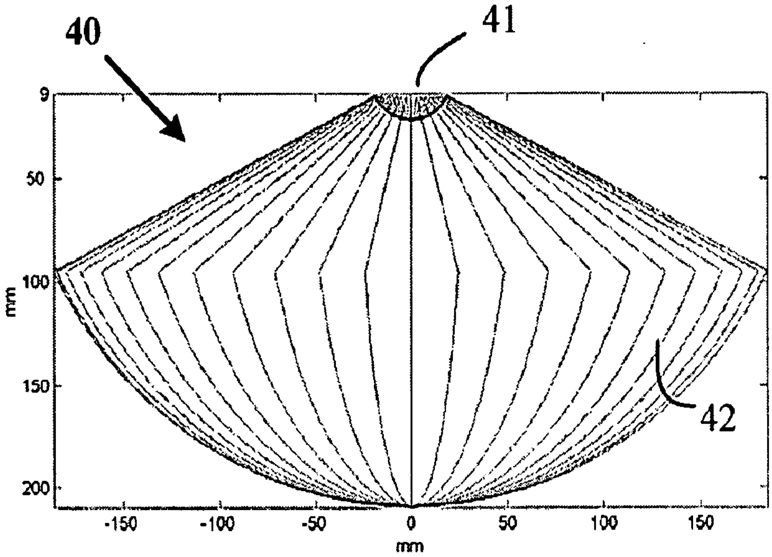

40
41
42
9
50
100
150
200
mm
-150
-100
-50
0
50
100
150
mm

Fig. 5D

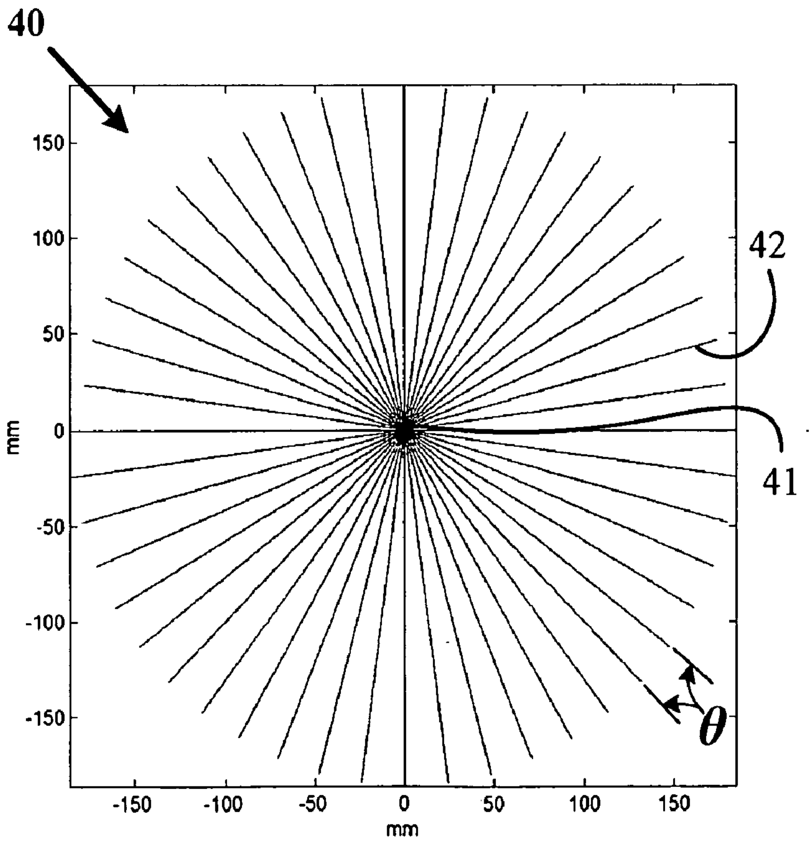

40
150
100
50
0
-50
-100
-150
mm
42
41
θ
-150
-100
-50
0
50
100
150
mm

Fig. 5E

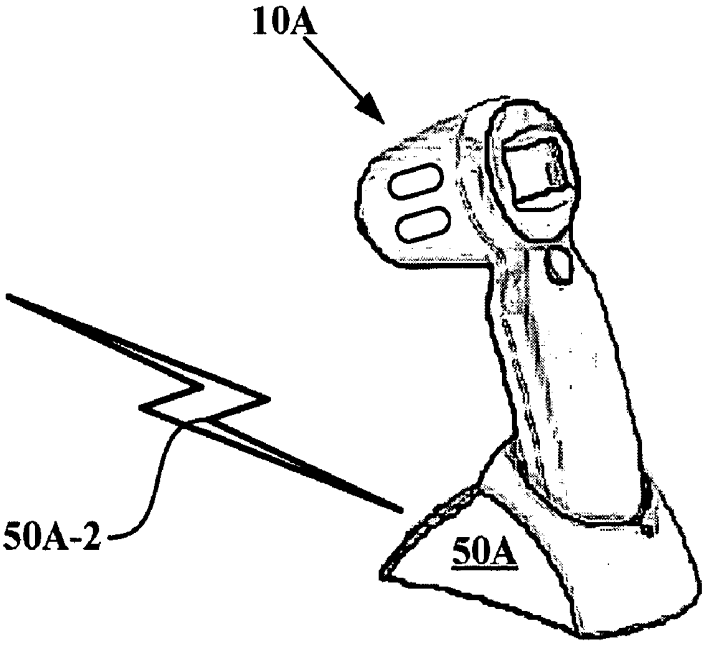


Fig. 6

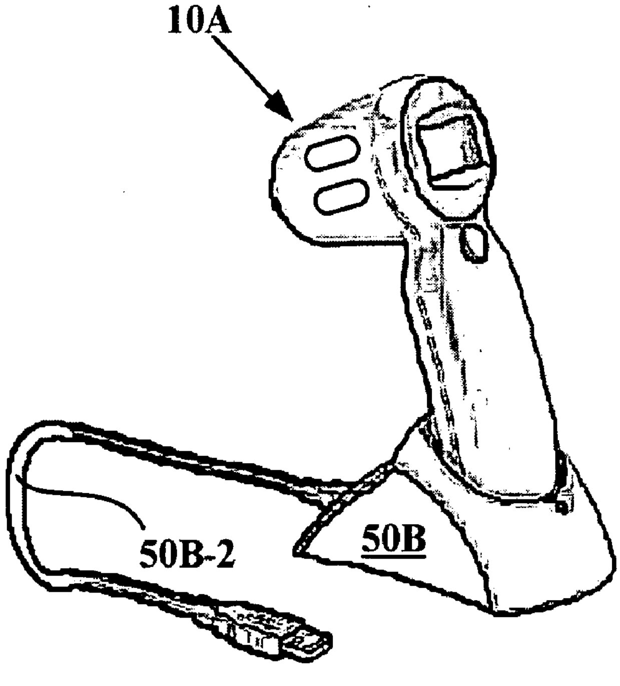


Fig. 7

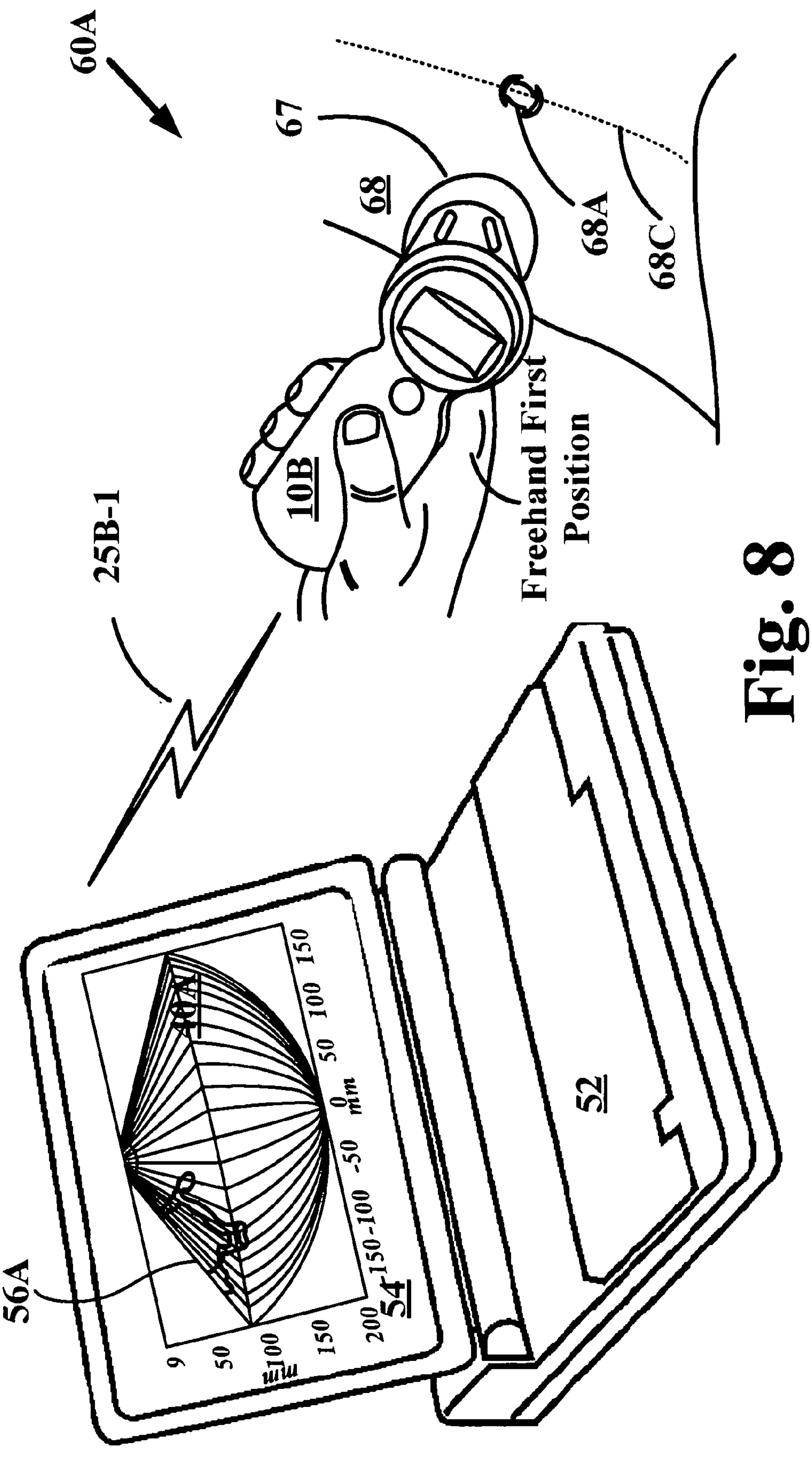

60A
67
68
68A
68C
25B-1
10B
Freehand First Position
56A
40A
54
52
9
50
100
150
200
mm
150
-100
-50
0
mm
50
100
150

Fig. 8

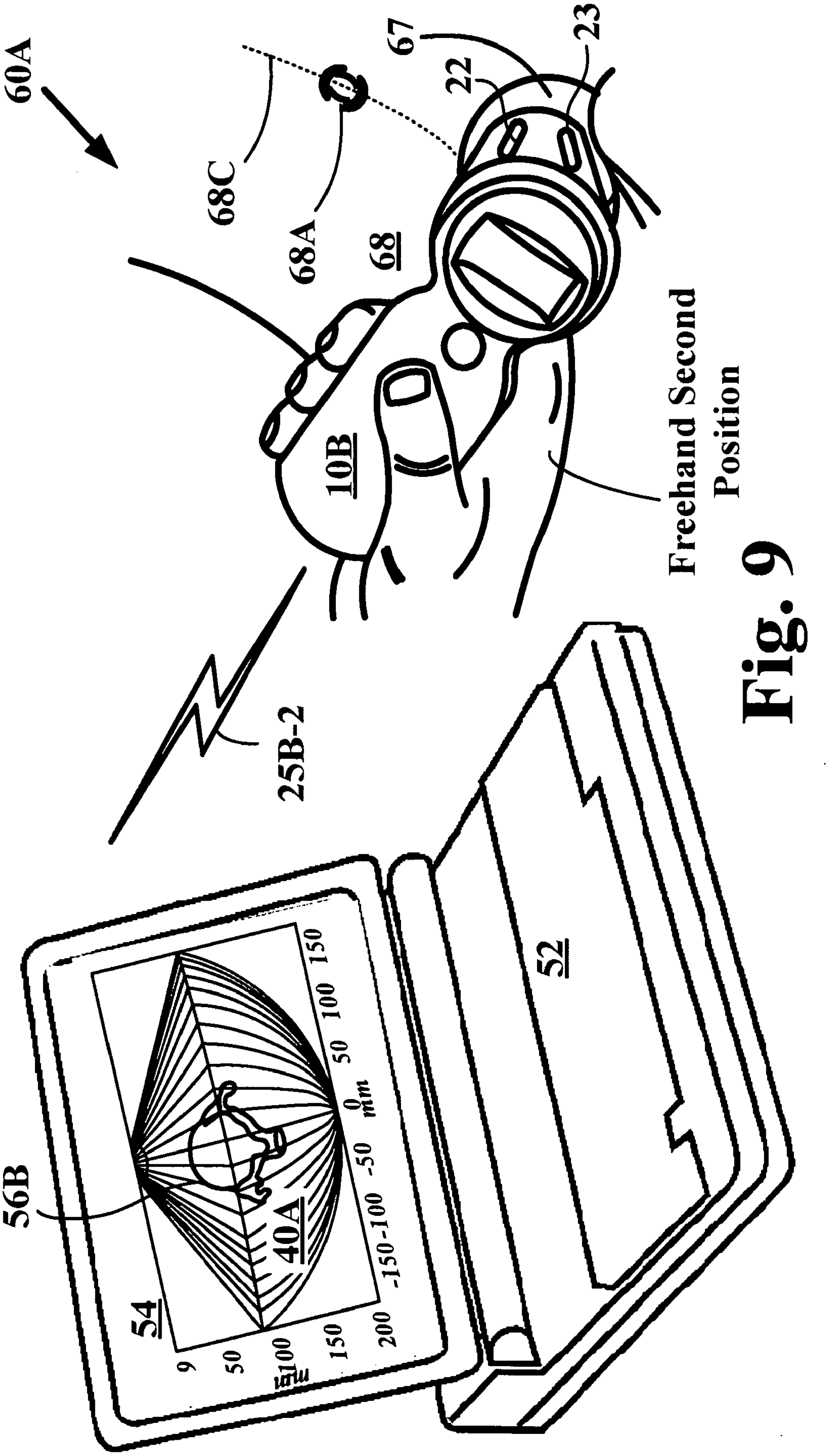

60A
68C
θ
68A
67
22
23
68
10B
Freehand Second Position
25B-2
56B
54
40A
52
9
50
100
150
200
mm
-150
-100
-50
0
mm
50
100
150

Fig. 9

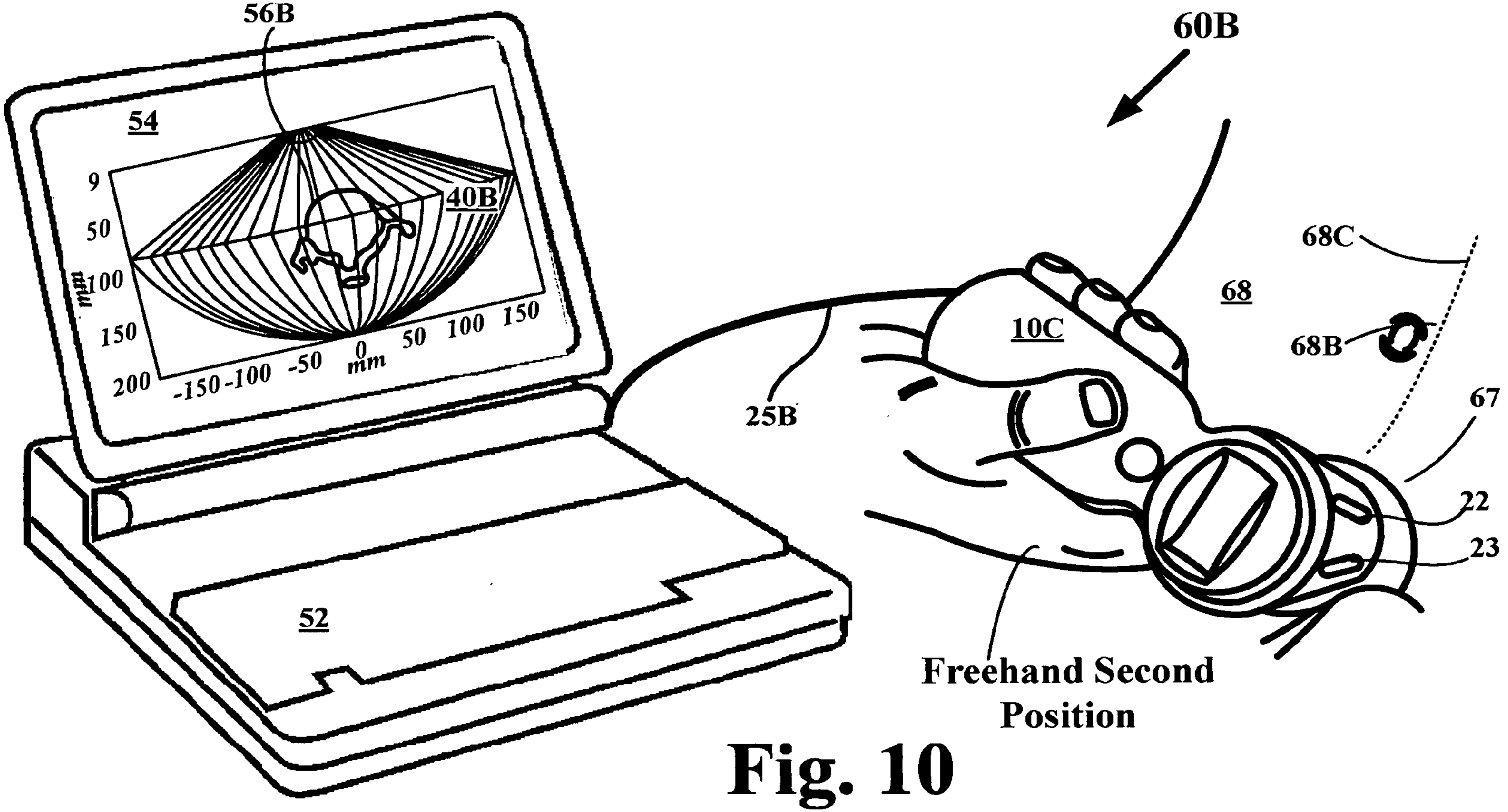

60B
56B
54
40B
9
50
100
150
200
mm
-150
-100
-50
0
mm
50
100
150
52
25B
10C
68
68C
68B
67
22
23
Freehand Second Position

Fig. 10

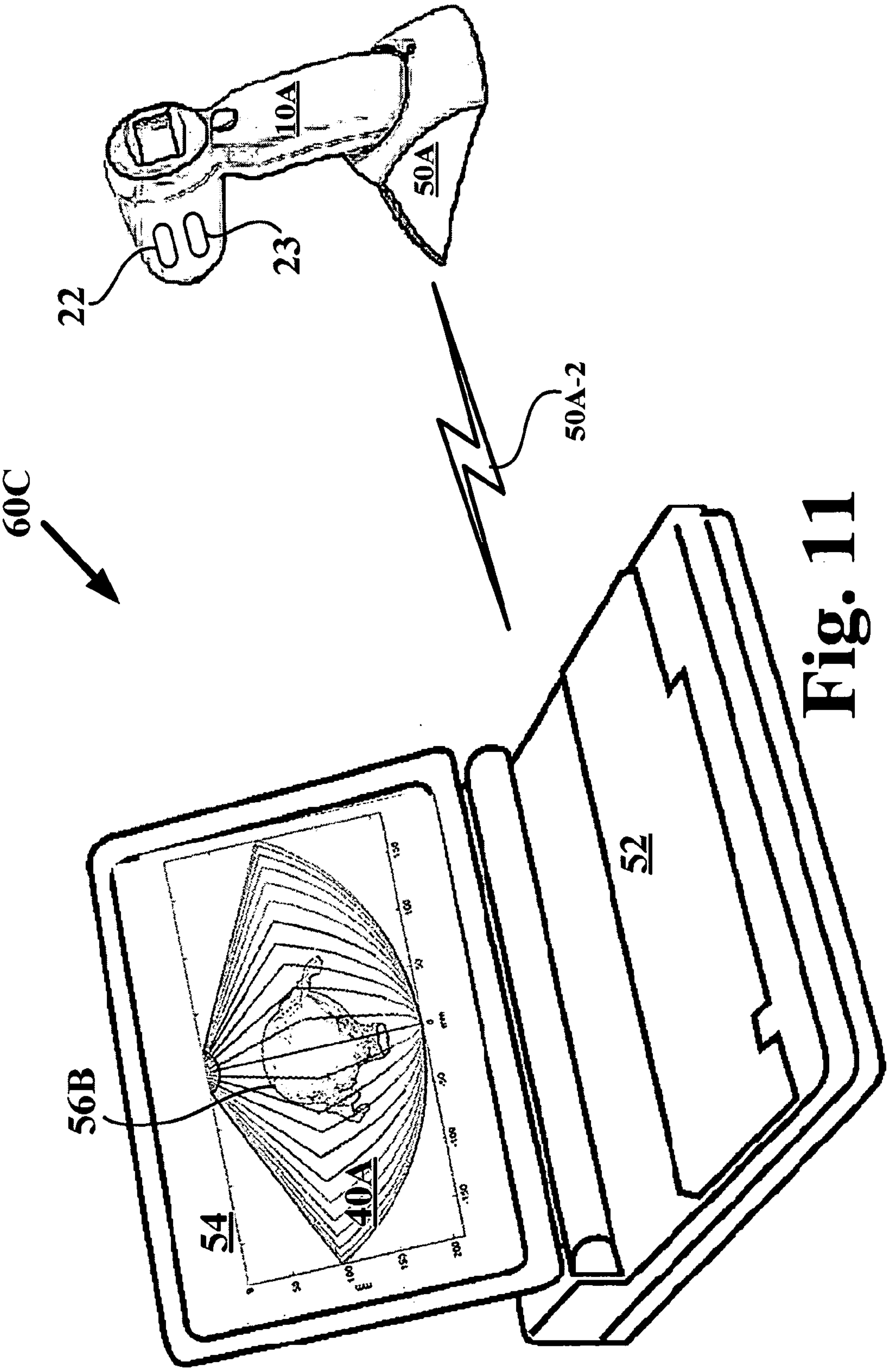


Fig. 11

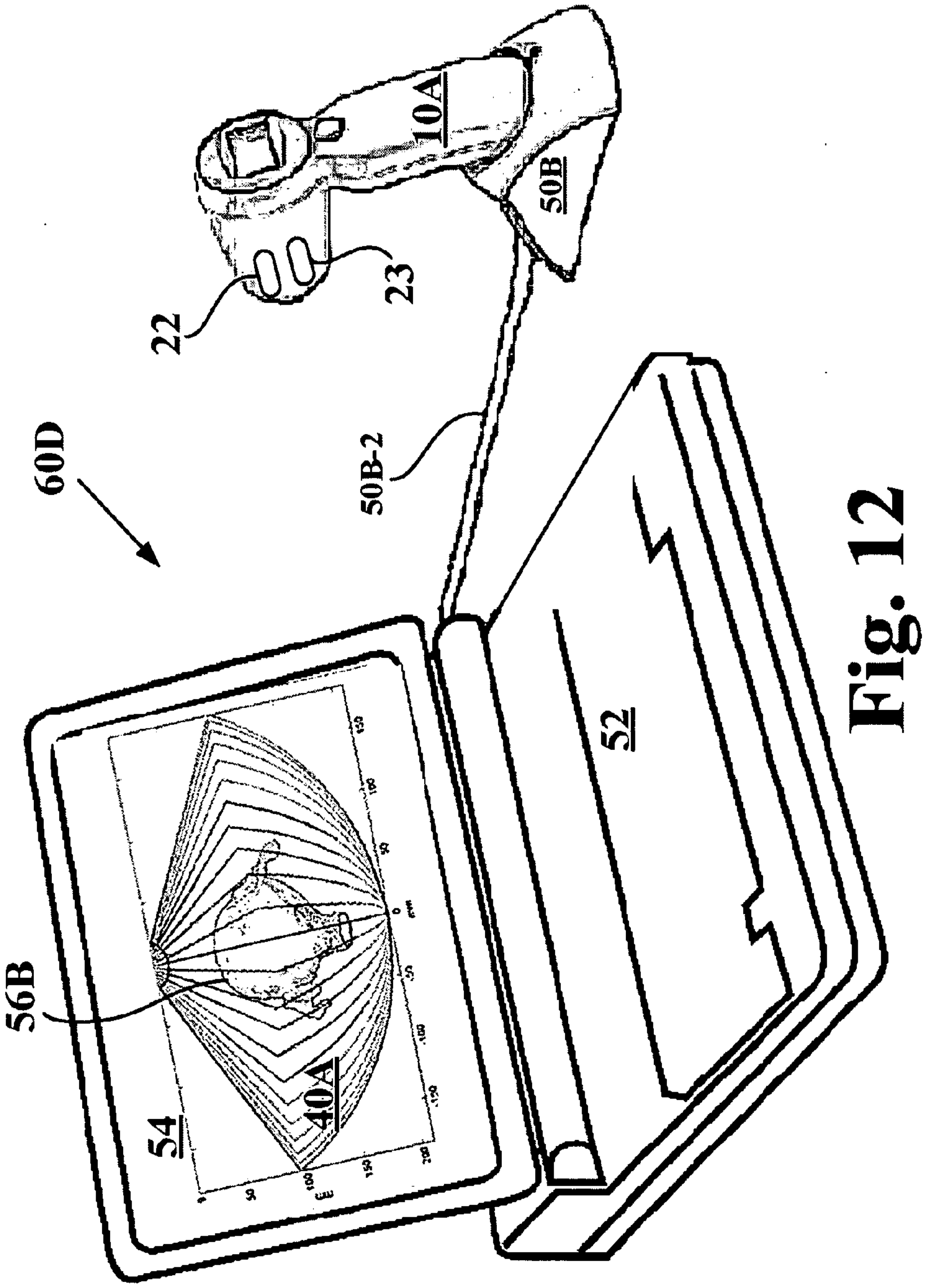

60D
22
23
10A
50B
50B-2
56B
54
40A
52
0
50
100
150
200
mm
-150
-100
-50
0
50
100
150

Fig. 12

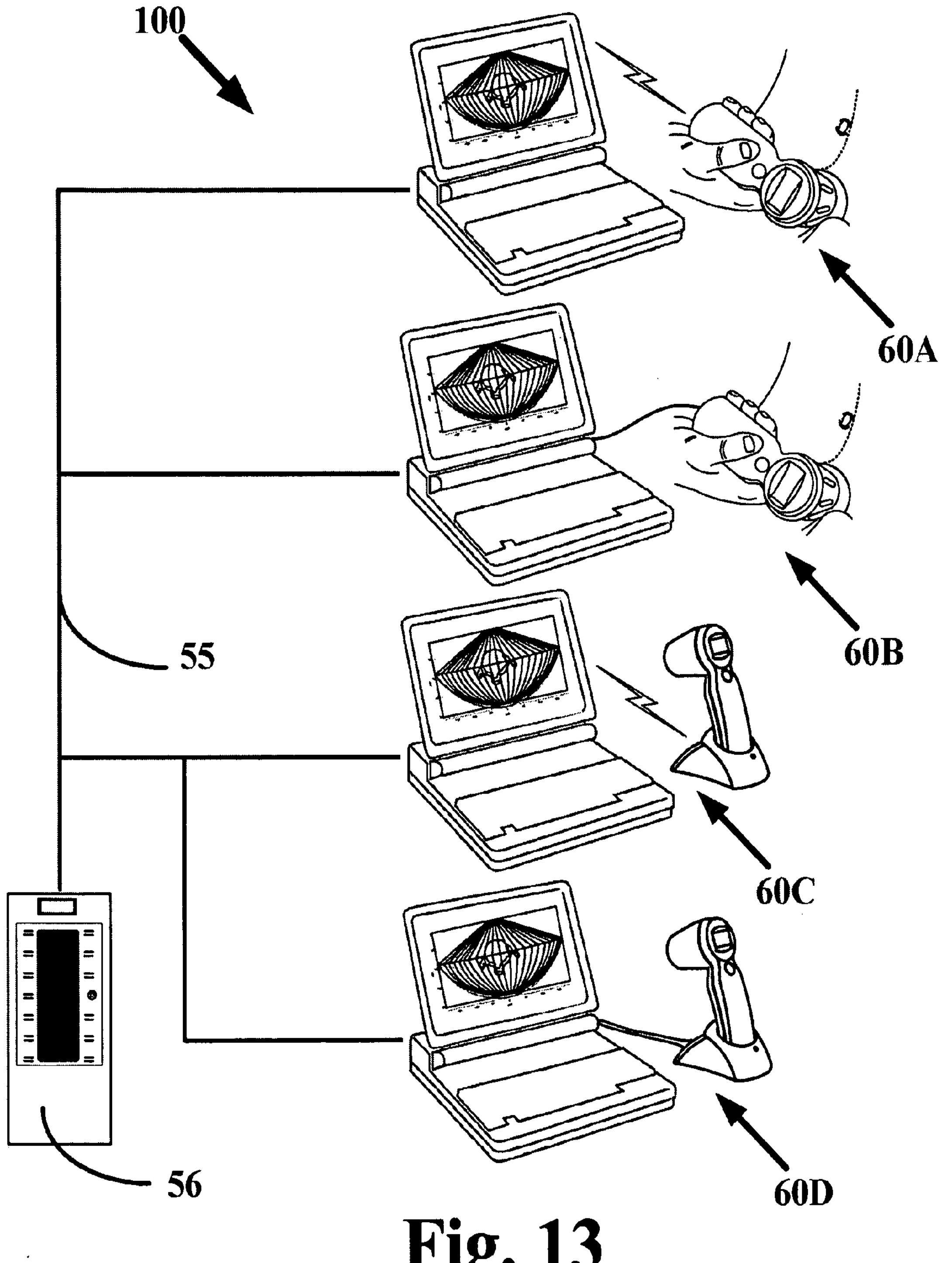


Fig. 13

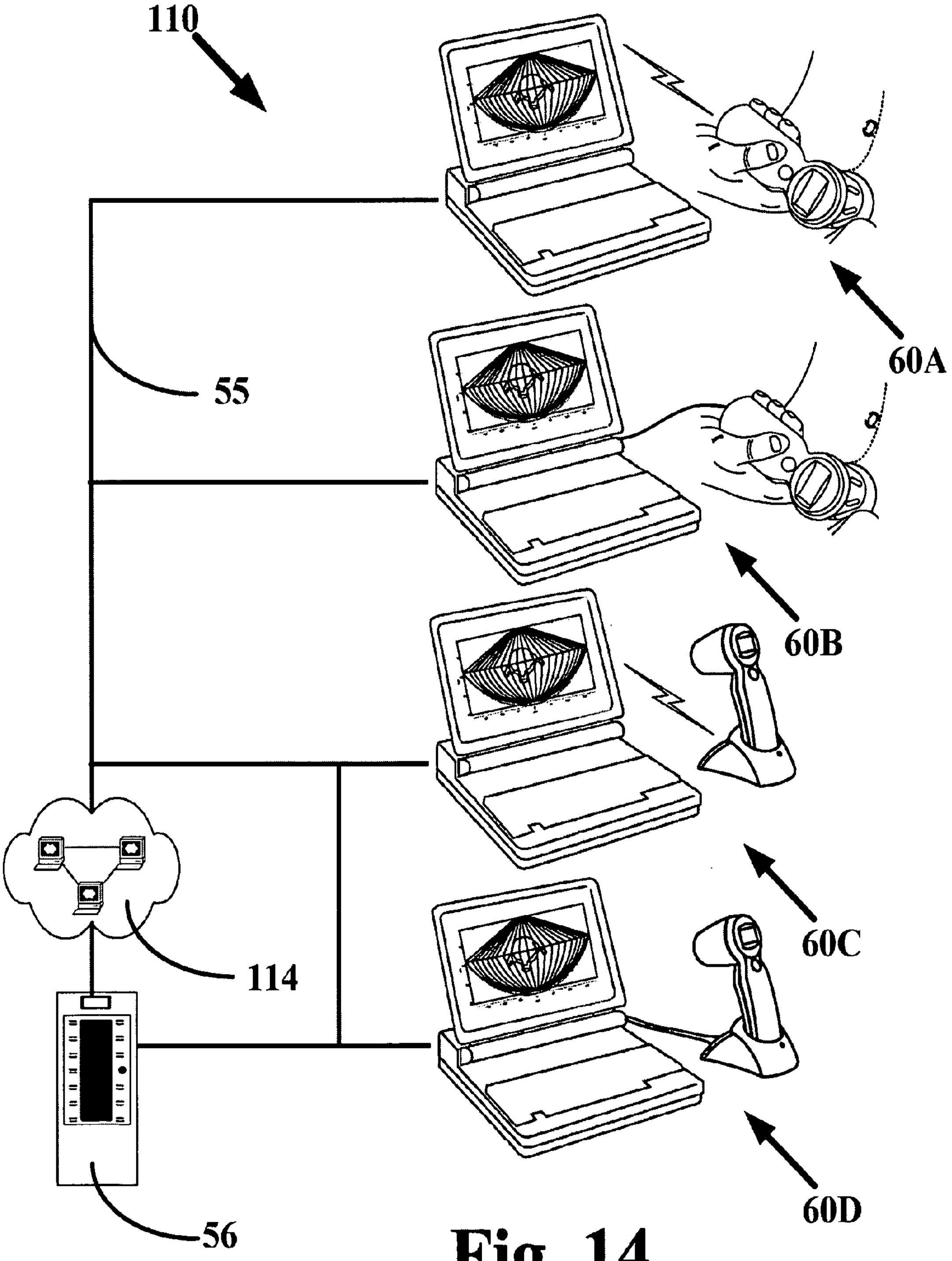


Fig. 14

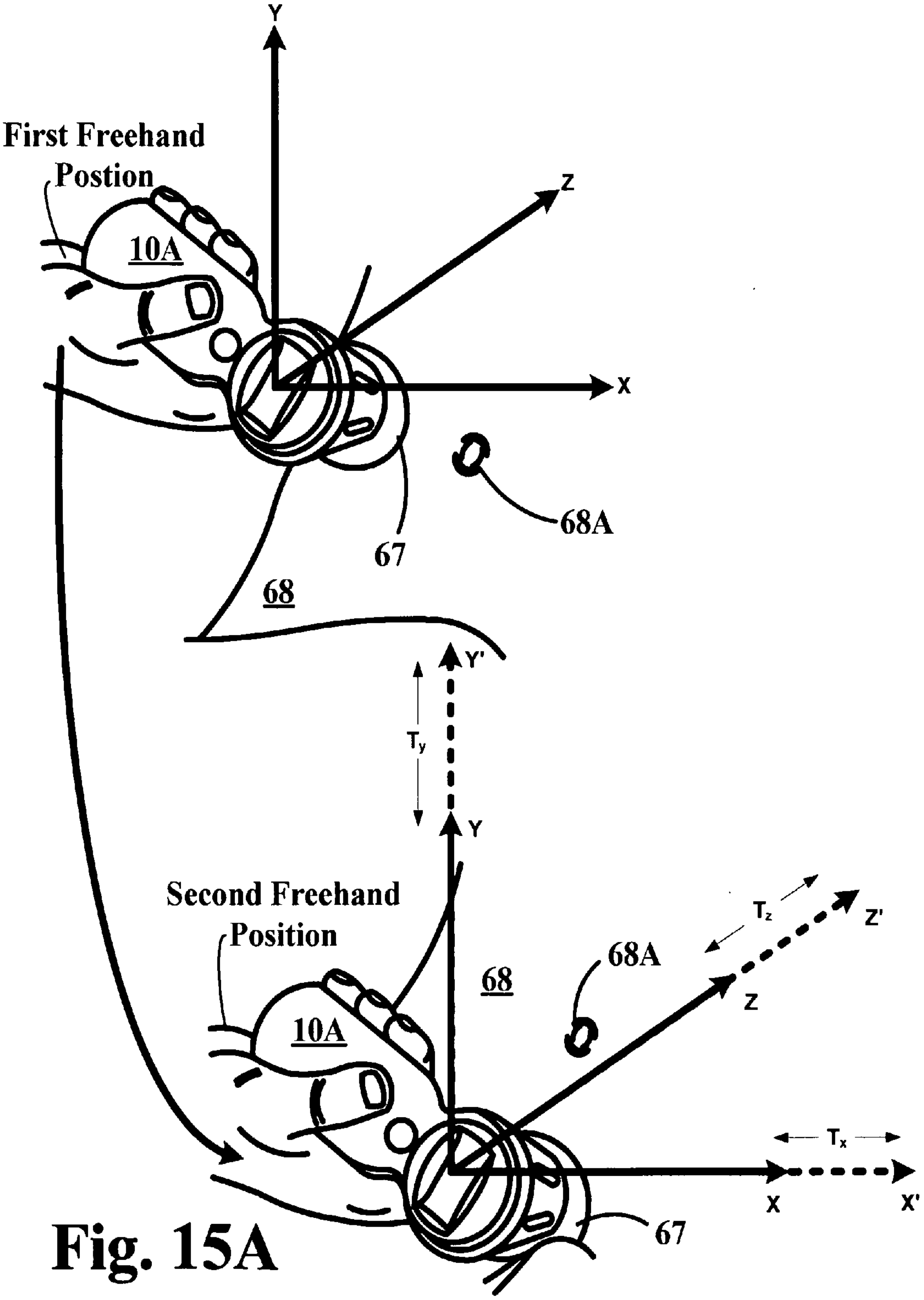

Y
First Freehand
Postion
10A
Z
X
68A
67
68
Y'
T_y
Y
Second Freehand
Position
T_z
Z'
68A
68
10A
Z
T_x
X
X'
67

Fig. 15A

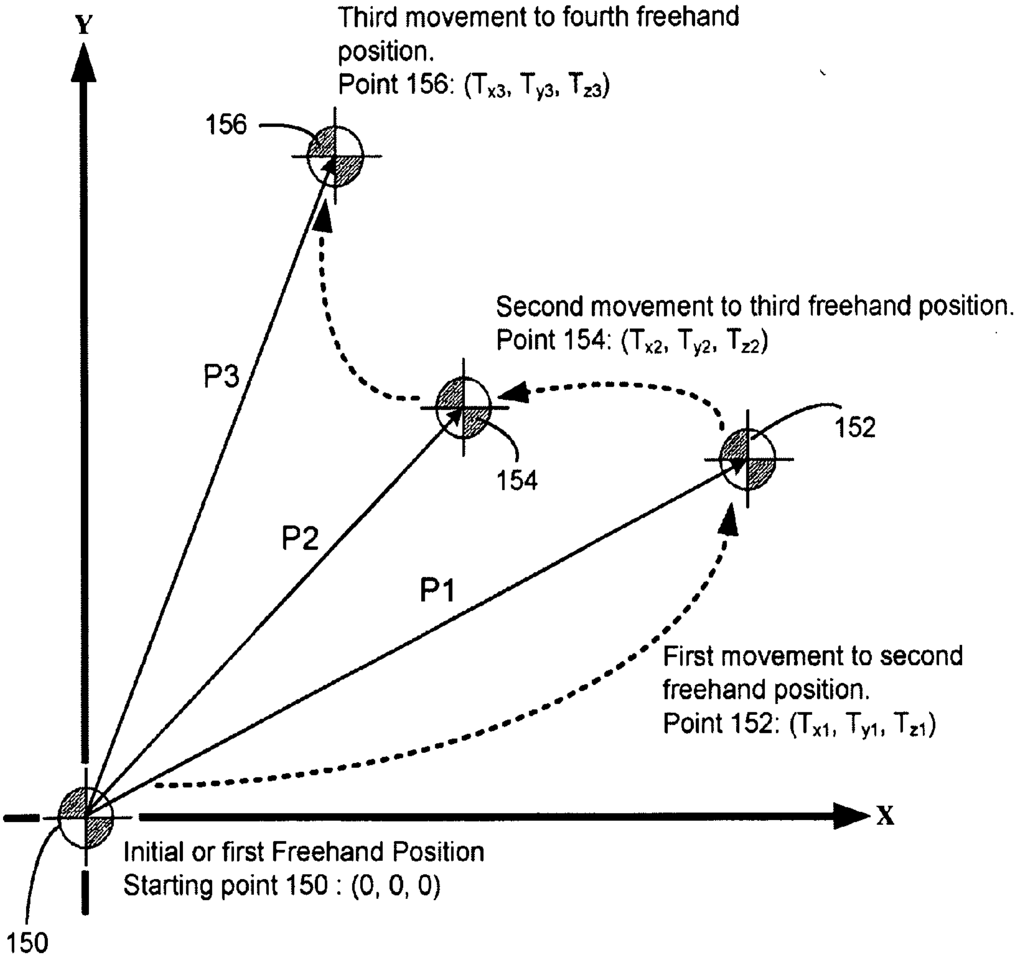

Y
Third movement to fourth freehand position.
Point 156: (T_{x3}, T_{y3}, T_{z3})
156
Second movement to third freehand position.
Point 154: (T_{x2}, T_{y2}, T_{z2})
P3
152
154
P2
P1
First movement to second freehand position.
Point 152: (T_{x1}, T_{y1}, T_{z1})
X
Initial or first Freehand Position
Starting point 150 : (0, 0, 0)
150

Fig. 15B

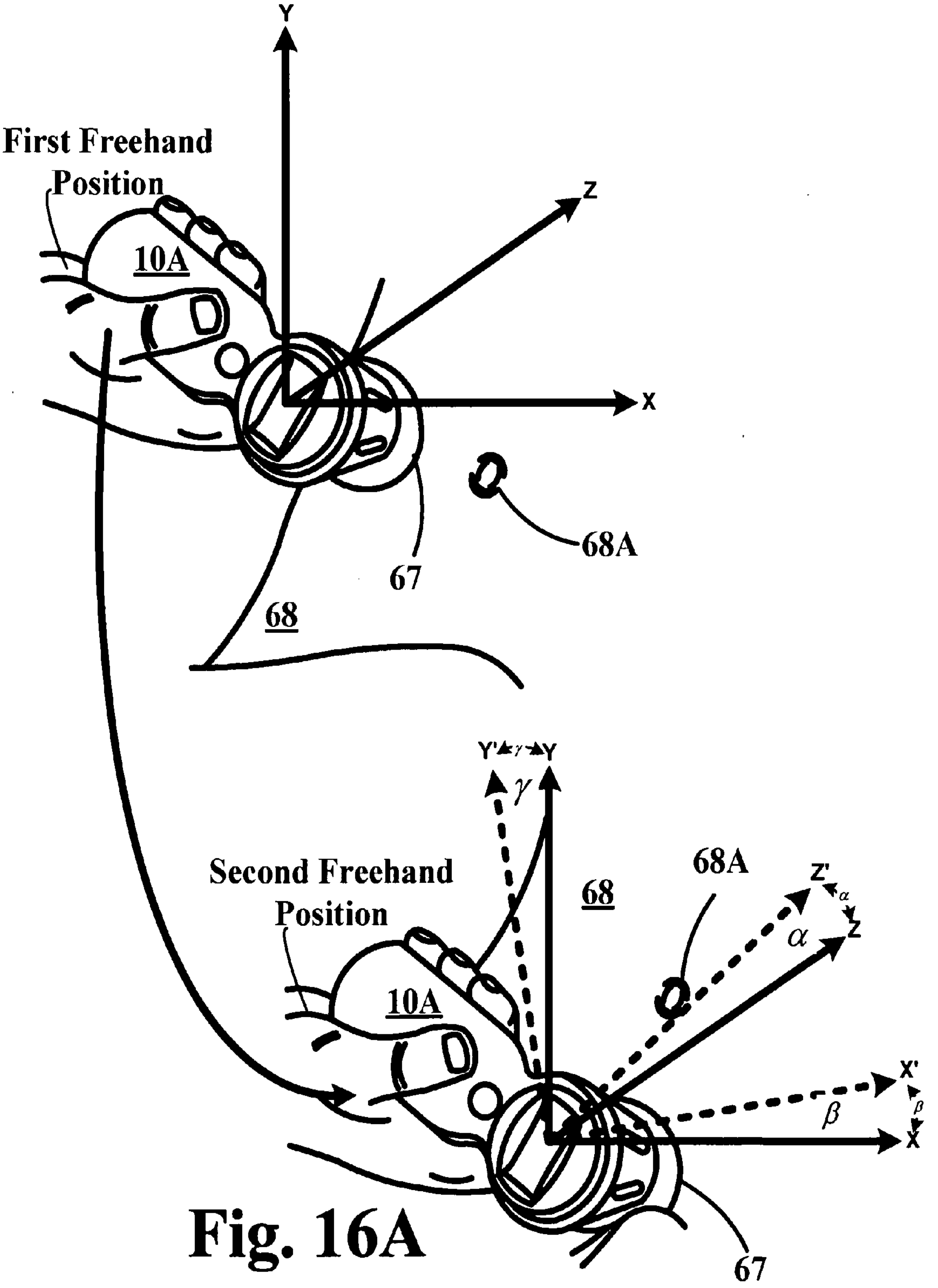

Y
First Freehand Position
Z
10A
X
68A
67
68
Y' γ Y
γ
Second Freehand Position
68
68A
Z'
α
α
Z
10A
X'
β
β
X
67

Fig. 16A

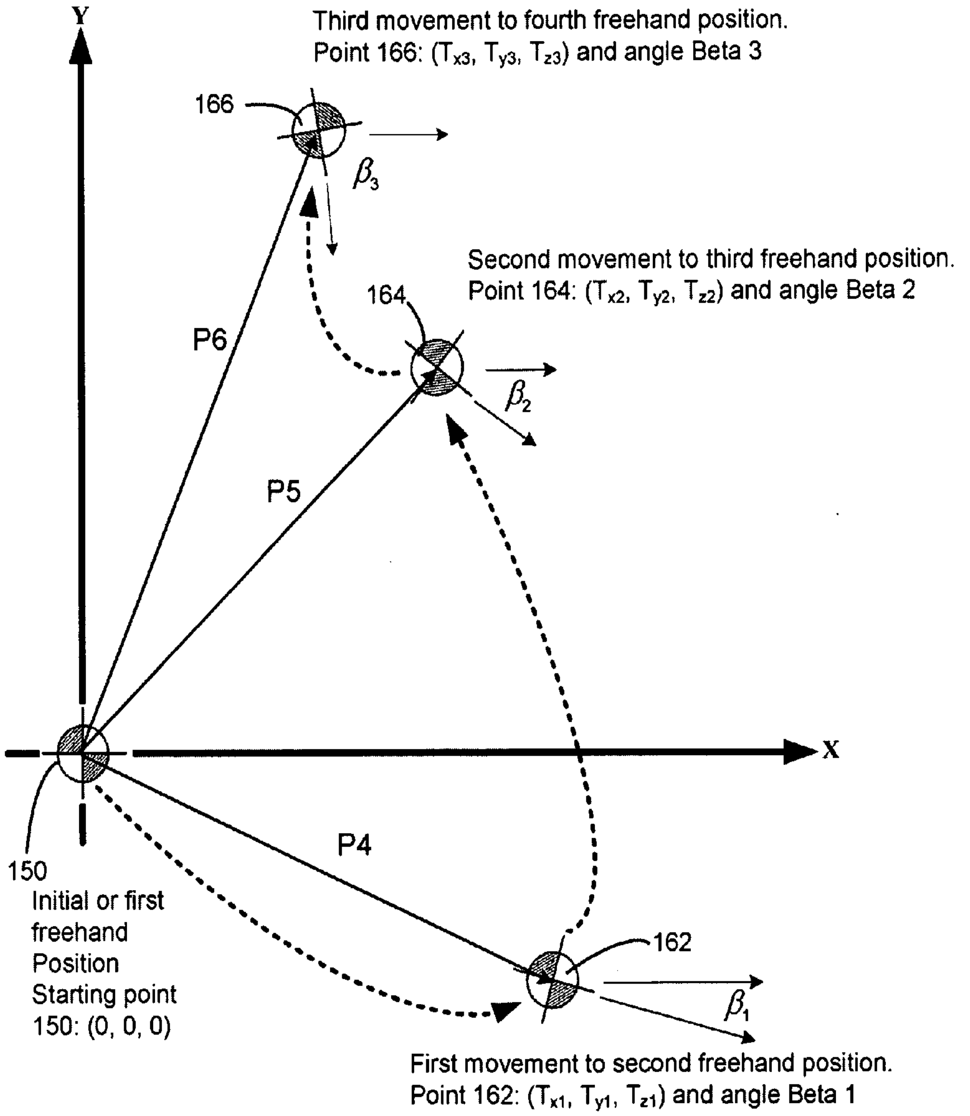

Y
Third movement to fourth freehand position.
Point 166: (T_{x3}, T_{y3}, T_{z3}) and angle Beta 3
166
β_3
Second movement to third freehand position.
Point 164: (T_{x2}, T_{y2}, T_{z2}) and angle Beta 2
164
P6
β_2
P5
X
P4
150
Initial or first freehand Position
Starting point 150: (0, 0, 0)
162
β_1
First movement to second freehand position.
Point 162: (T_{x1}, T_{y1}, T_{z1}) and angle Beta 1

Fig. 16B

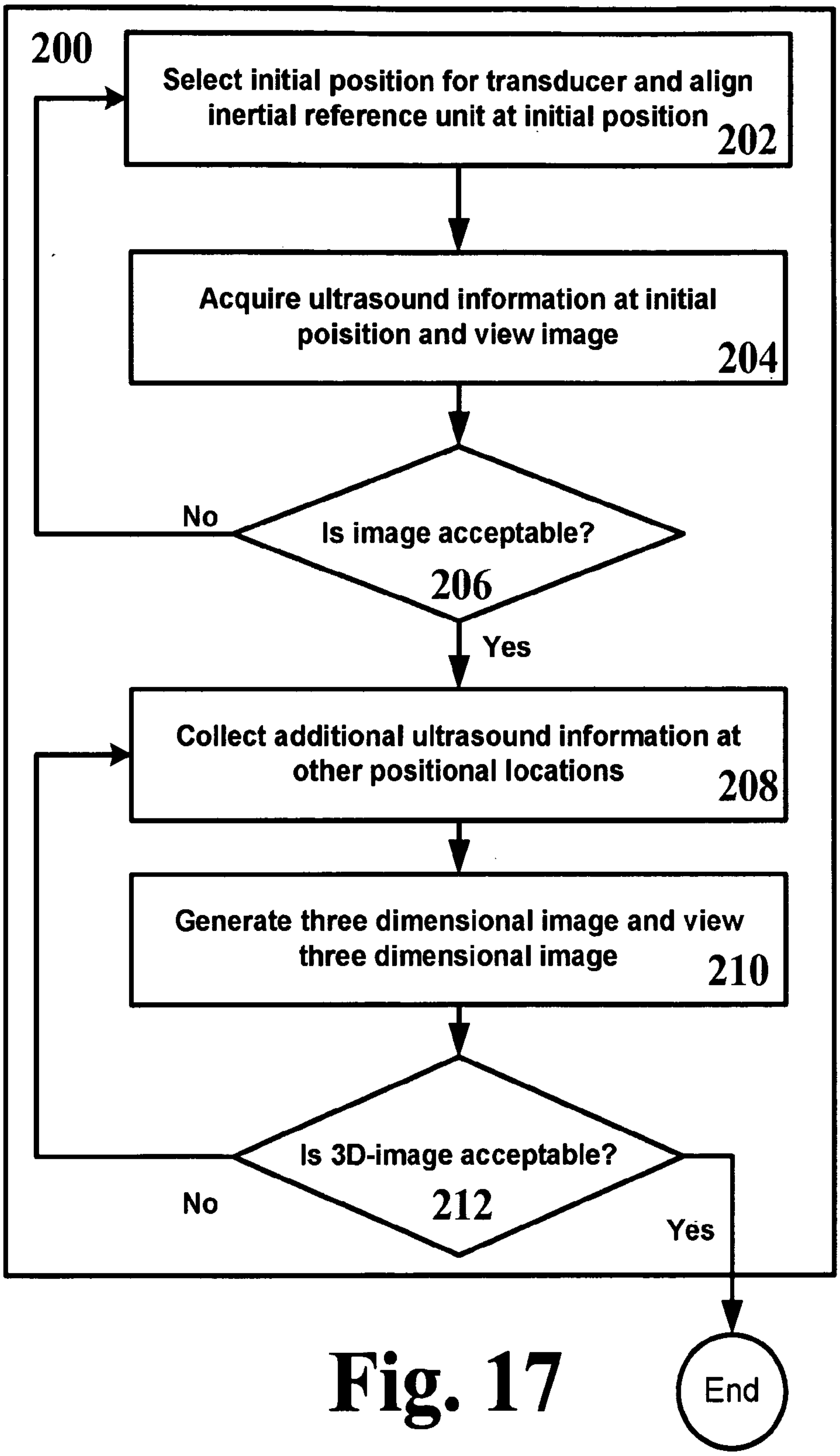

200
Select initial position for transducer and align inertial reference unit at initial position
202
Acquire ultrasound information at initial poisition and view image
204
Is image acceptable?
206
No
Yes
Collect additional ultrasound information at other positional locations
208
Generate three dimensional image and view three dimensional image
210
Is 3D-image acceptable?
212
No
Yes
End

Fig. 17

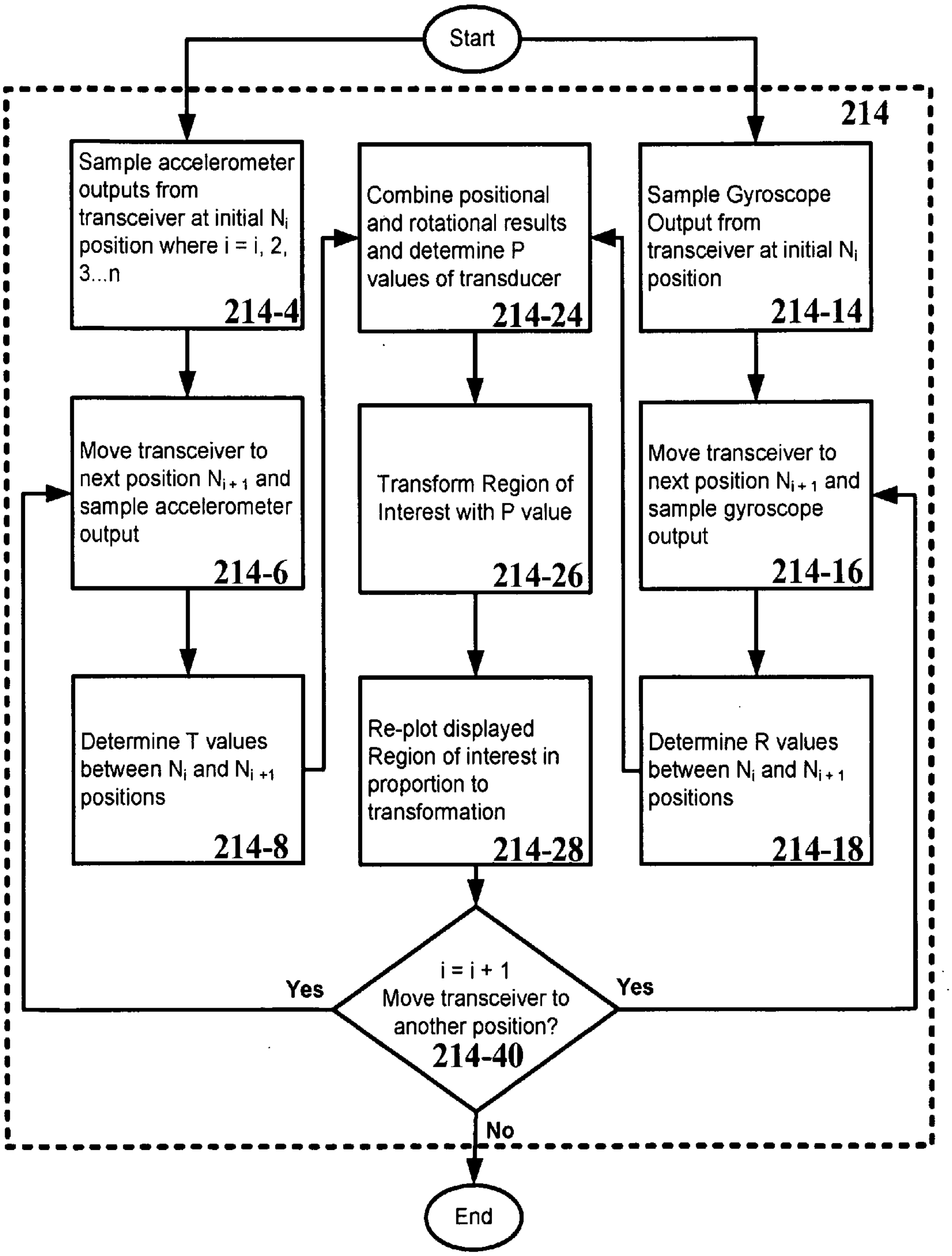

Start
214
Sample accelerometer outputs from transceiver at initial N_i position where i = i, 2, 3...n
214-4
Move transceiver to next position N_{i+1} and sample accelerometer output
214-6
Determine T values between N_i and N_{i+1} positions
214-8
Combine positional and rotational results and determine P values of transducer
214-24
Transform Region of Interest with P value
214-26
Re-plot displayed Region of interest in proportion to transformation
214-28
Sample Gyroscope Output from transceiver at initial N_i position
214-14
Move transceiver to next position N_{i+1} and sample gyroscope output
214-16
Determine R values between N_i and N_{i+1} positions
214-18
Yes
i = i + 1
Move transceiver to another position?
214-40
Yes
No
End

Fig. 18

SYSTEMS AND METHODS FOR ULTRASOUND IMAGING USING AN INERTIAL REFERENCE UNIT

FIELD OF THE INVENTION

[0001] This invention relates generally to ultrasound imaging, and more specifically, to systems and methods for ultrasound imaging using inertial reference units. SUMMARY OF THE INVENTION

[0002] The disclosed embodiments of the present invention are directed to systems and methods for ultrasound imaging using an inertial reference unit. In one aspect, an ultrasound imaging system includes an ultrasound unit configured to ultrasonically scan a plurality of planes within a region of interest in a subject and generate imaging information from the scans. An inertial reference unit is provided that detects relative positions of the ultrasound unit as the ultrasound unit scans the plurality of planes. A processing unit is configured to receive the imaging information and the corresponding detected positions and is operable to generate three dimensional images of the region of interest.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] FIG. **1** is a block diagrammatic view of an ultrasound;

[0004] FIG. **1**A is a side elevation view of an ultrasound transceiver that includes an inertial reference unit;

[0005] FIG. **1**B is a side elevation view of an ultrasound transceiver that includes an inertial reference unit;

[0006] FIG. **1**C is a side elevation view of an ultrasound transceiver that includes an inertial reference unit;

[0007] FIG. **1**D is a side elevation view of an ultrasound transceiver that includes an inertial reference unit contained within a detachable collar;

[0008] FIG. **1**E is side elevation view of another ultrasound transceiver that includes an inertial reference unit contained within a detachable collar;

[0009] FIG. **2**A is a schematic illustration of the accelerometer of the transceivers **10**A-**10**E of FIGS. **1**A-**1**E, respectively;

[0010] FIG. **2**B is an expansion of the schematic illustration of FIG. **2**A;

[0011] FIG. **3**A is a schematic illustration of a gyroscope of transceivers **10**A-**10**E of FIGS. **1**A-**1**E, respectively;

[0012] FIG. **3**B is an expansion of the schematic illustration of FIG. **3**A;

[0013] FIG. **4** is a graphical representation of three dimensional (3D) distributed scan lines emanating from a transceiver that cooperatively form a scan cone;

[0014] FIG. **5**A is a graphical representation of a plurality of scan planes that form a three-dimensional (3D) array having a substantially conical shape;

[0015] FIG. **5**B is a graphical representation of scan plane;

[0016] FIG. **5**C a graphical representation of a plurality of scan lines emanating from a hand-held ultrasound transceiver forming a single scan plane cross-sectioning through portions of an organ;

[0017] FIG. **5**D is an isometric view of an ultrasound scan cone that projects outwardly from the transceivers of FIGS. **1**A-E;

[0018] FIG. **5**E is a top plan view of the scan cone **40** of FIG. **5**D;

[0019] FIG. **6** is a schematic depiction of a transceiver housed in a cradle equipped for wireless communication;

[0020] FIG. **7** is a schematic depiction of a transceiver housed in a cradle equipped for cabled communication;

[0021] FIG. **8** is an isometric view of an inertial ultrasound imaging system using the transceiver of FIG. **1**B applied to a side abdominal region of a patient;

[0022] FIG. **9** is an isometric view of an inertial ultrasound imaging system using the transceiver of FIG. **1**B applied to a center abdominal region of a patient;

[0023] FIG. **10** is an isometric view of an inertial ultrasound imaging system using the transceiver of FIG. **1**C applied to a center abdominal region of a patient;

[0024] FIG. **11** is an isometric view of an inertial ultrasound imaging system using the transceiver of FIG. **1**A housed in a cradle configured for wireless communication;

[0025] FIG. **12** is an isometric view of an inertial ultrasound imaging system using the transceiver of FIG. **1**A housed in a cradle configured for electrical cable communication;

[0026] FIG. **13** is a schematic illustration of a server-accessed local area network in communication with the inertial ultrasound imaging systems of FIGS. **9**-**12**;

[0027] FIG. **14** is a schematic illustration of the Internet in communication with the inertial ultrasound imaging systems of FIGS. **9**-**12**;

[0028] FIG. **15**A is a schematic illustration of inertial reference coordinates superimposed over a transceiver experiencing translation changes between two transceiver locations regions;

[0029] FIG. **15**B is an illustration that will be used to further describe the operation of the transceiver **10**A of FIGS. **1**A and **15**A as a series of translation movements from an initial freehand position;

[0030] FIG. **16**A is a schematic illustration of inertial reference coordinates superimposed over a transceiver experiencing rotation and tilt changes between two transceiver locations regions;

[0031] FIG. **16**B is a schematic illustration that will be used to further describe the method of FIG. **16**A involving a series of translation and rotation movements from an initial freehand position;

[0032] FIG. **17** is a flowchart that will be used to describe a method of forming a three dimensional ultrasound image, according to an embodiment of the invention. a method algorithm of the particular embodiments; and

[0033] FIG. **18** is a flowchart that will be used to further describe the method of FIG. **17**, an expansion of sub algorithm **212** from FIG. **16**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0034] The following applications are incorporated by reference as if fully set forth herein: U.S. application Ser. Nos. 11/222,360 filed Sep. 8, 2005 and 10/058,269 filed Jan. 30, 2002.

[0035] The following description and FIGS. **1** through **18** provide a thorough understanding of certain embodiments. One skilled in the art, however, will understand that the present invention may have additional embodiments, or that the present invention may be practiced without several of the details described in the following description.

[0036] According to an embodiment, FIG. **1** is a block diagrammatic view of an ultrasound system **1**. System **1** includes an ultrasound unit **2** that is operable to ultrasonically scan an anatomical portion. Ultrasound unit **2** may include one or more, or a linear or non-linear array of piezoelectric elements operable to project ultrasound energy into the anatomical region, and to receive reflections from structures positioned within the anatomical region. The piezoelectric elements and/or the array may be stationary within the ultrasound unit **2**, or an actuator may be provided that rotates and/or oscillates and/or otherwise moves the elements of the array so that the anatomical region may be periodically scanned by the array.

[0037] The system **1** also includes an inertial reference unit **3** that is operable to generate acceleration and angular rate information for the ultrasound unit **2**. The inertial reference unit **2** may include a device that is configured to sense an acceleration associated with a directional motion of the ultrasound unit **2**. The inertial reference unit **2** may also include at least one device that is operable to sense angular rate information associated with the directional motion of the ultrasound unit **2**. Accordingly, a device that is configured to maintain angular position or rigidity with respect to a fixed set of reference coordinates **4** may be used. The inertial reference unit **3** may be incorporated into a structural portion of the ultrasound unit **2**, or it may be a detachable accessory to the ultrasound unit **2**.

[0038] Ultrasound unit **2** and inertial reference unit **3** are coupled to a processor unit **5**. Processor unit **5** is configured to generate radio frequency excitation for ultrasound unit **2**, and to receive signals generated by ultrasound unit **2** that result from the reflected acoustic waves. Accordingly, processor unit **5** may include a transmit/receive circuit that is coupled to respective transmitter and receiver circuits, and a suitable control circuit that permits the transmitter, receiver and the transmit/receive circuit to cooperatively insonify a desired anatomical region. The processor unit **5** may also include suitable algorithms that are configured to receive acceleration and/or angular rate information from the inertial reference unit **3**, and/or to integrate the acceleration and/or angular rate information along a kinematic path of the ultrasound unit **2** to generate translational and angular position information for the ultrasound unit **2**. Processor unit **5** is also operable to receive two-dimensional ultrasound information from the ultrasound unit **2** and to process information to generate a plurality of two-dimensional ultrasound images. The two-dimensional ultrasound images may be combined with the translational and/or angular position information so that a three-dimensional image of the insonified region may be generated. The processor unit **5** may also include various other devices, such as a video processor, a video memory device and a display device. Processor unit **5** may be a separate unit, such as a "mainframe" processor, or it may be incorporated into other devices, such as ultrasound unit **2**. Further, it will be appreciated that FIG. **1** does not necessarily illustrate every component of the system **1**. Instead, emphasis is placed upon the components that are most relevant to the following disclosed apparatus and methods.

[0039] FIG. **1**A is a side elevation view of an ultrasound transceiver **10**A that includes an inertial reference unit, according to an embodiment of the invention. The transceiver **10**A includes a transceiver housing **18** having an outwardly extending handle **12** suitably configured to allow a user to manipulate the transceiver **10**A relative to a patient. The handle **12** includes a trigger **14** that allows the user to initiate an ultrasound scan of a selected anatomical portion, and a cavity selector **16**. The cavity selector **16** will be described in greater detail below. The transceiver **10**A also includes a transceiver dome **20** that contacts a surface portion of the patient when the selected anatomical portion is scanned. The dome **20** generally provides an appropriate acoustical impedance match to the anatomical portion and/or permits ultrasound energy to be properly focused as it is projected into the anatomical portion. The transceiver **10**A further includes one, or preferably an array of separately excitable ultrasound transducer elements (not shown in FIG. **1**A) positioned within or otherwise adjacent with the housing **18**. The transducer elements are suitably positioned within the housing **18** or otherwise to project ultrasound energy outwardly from the dome **20**, and to permit reception of acoustic reflections generated by internal structures within the anatomical portion. The one or more array of ultrasound elements may include a one-dimensional, or a two-dimensional array of piezoelectric elements that are moved within the housing **18** by a motor. Alternately, the array may be stationary with respect to the housing **18** so that the selected anatomical region is scanned by selectively energizing the elements in the array.

[0040] Transceiver **10**A includes an inertial reference unit that includes an accelerometer **22** and/or gyroscope **23** positioned preferably within or adjacent to housing **18**. The accelerometer **22** is operable to sense an acceleration of the transceiver **10**A, preferably relative to a coordinate system, while the gyroscope **23** is operable to sense an angular velocity of the transceiver **10**A relative to the same or another coordinate system. Accordingly, the gyroscope **23** may be of conventional configuration that employs dynamic elements, or it may be an optoelectronic device, such as the known optical ring gyroscope. In one embodiment, the accelerometer **22** and the gyroscope **23** may include a commonly-packaged and/or solid-state device. One suitable commonly packaged device is the MT6 miniature inertial measurement unit, available from Omni Instruments, Incorporated, although other suitable alternatives exist. In other embodiments, the accelerometer **22** and/or the gyroscope **23** may include commonly packaged micro-electromechanical system (MEMS) devices, which are commercially available from MEMSense, Incorporated. As described in greater detail below, the accelerometer **22** and the gyroscope **23** cooperatively permit the determination of positional and/or angular changes relative to a known position that is proximate to an anatomical region of interest in the patient.

[0041] The transceiver **10**A includes (or if capable at being in signal communication with) a display **24** operable to view processed results from an ultrasound scan, and/or to allow an operational interaction between the user and the transceiver **10**A. For example, the display **24** may be configured to display alphanumeric data that indicates a proper and/or an optimal position of the transceiver **10**A relative to the selected anatomical portion. Display **24** may be used to view two- or three-dimensional images of the selected anatomical region. Accordingly, the display **24** may be a liquid crystal display (LCD), a light emitting diode (LED) display, a cathode ray tube (CRT) display, or other suitable display devices operable to present alphanumeric data and/or graphical images to a user.

[0042] Still referring to FIG. **1**A, a cavity selector **16** is operable to adjustably adapt the transmission and reception of ultrasound signals to the anatomy of a selected patient. In particular, the cavity selector **16** adapts the transceiver **10**A to accommodate various anatomical details of male and female patients. For example, when the cavity selector **16** is adjusted to accommodate a male patient, the transceiver **10**A is suitably configured to locate a single cavity, such as a urinary bladder in the male patient. In contrast, when the cavity selector **16** is adjusted to accommodate a female patient, the transceiver **10**A is configured to image an anatomical portion having multiple cavities, such as a bodily region that includes a bladder and a uterus. Alternate embodiments of the transceiver **10**A may include a cavity selector **16** configured to select a single cavity scanning mode, or a multiple cavity-scanning mode that may be used with male and/or female patients. The cavity selector **16** may thus permit a single cavity region to be imaged, or a multiple cavity region, such as a region that includes a lung and a heart to be imaged.

[0043] To scan a selected anatomical portion of a patient, the transceiver dome **20** of the transceiver **10**A is positioned against a surface portion of a patient that is proximate to the anatomical portion to be scanned. The user actuates the transceiver **10**A by depressing the trigger **14**. In response, the transceiver **10** transmits ultrasound signals into the body, and receives corresponding return echo signals that are at least partially processed by the transceiver **10**A to generate an ultrasound image of the selected anatomical portion. In a particular embodiment, the transceiver **10**A transmits ultrasound signals in a range that extends from approximately about two megahertz (MHz) to approximately about ten MHz.

[0044] In one embodiment, the transceiver **10**A is operably coupled to an ultrasound system that is configured to generate ultrasound energy at a predetermined frequency and/or pulse repetition rate and to transfer the ultrasound energy to the transceiver **10**A. The system also includes a processor that is configured to process reflected ultrasound energy that is received by the transceiver **10**A to produce an image of the scanned anatomical region. Accordingly, the system generally includes a viewing device, such as a cathode ray tube (CRT), a liquid crystal display (LCD), a plasma display device, or other similar display devices, that may be used to view the generated image. The system may also include one or more peripheral devices that cooperatively assist the processor to control the operation of the transceiver **10**A, such a keyboard, a pointing device, or other similar devices. In still another particular embodiment, the transceiver **10**A may be a self-contained device that includes a microprocessor positioned within the housing **18** and software associated with the microprocessor to operably control the transceiver **10**A, and to process the reflected ultrasound energy to generate the ultrasound image. Accordingly, the display **24** is used to display the generated image and/or to view other information associated with the operation of the transceiver **10**A. For example, the information may include alphanumeric data that indicates a preferred position of the transceiver **10**A prior to performing a series of scans. In yet another particular embodiment, the transceiver **10**A may be operably coupled to a general-purpose computer, such as a laptop or a desktop computer that includes software that at least partially controls the operation of the transceiver **10**A, and also includes software to process information transferred from the transceiver **10**A, so that an image of the scanned anatomical region may be generated. The transceiver **10**A may also be optionally equipped with electrical contacts to make communication with accessory devices as discussed in FIGS. **6** and **7** below.

[0045] Although transceiver **10**A of FIG. **1**A may be used in any of the foregoing embodiments, other transceivers may also be used. For example, the transceiver may lack one or more features of the transceiver **10**A. For example, a suitable transceiver need not be a manually portable device, and/or need not have a top-mounted display, and/or may selectively lack other features or exhibit further differences.

[0046] FIG. **1**B is a side elevation view of an ultrasound transceiver **10**B that includes an inertial reference unit, according to another embodiment of the invention. Many of the details of the ultrasound transceiver **10**B have been discussed in connection with FIG. **1**A, and in the interest of brevity, will not be repeated. The transceiver **10**B is optionally configured to communicate signals wirelessly to other external devices. For example, wireless signals **25**B may include imaging data and/or positional information acquired by the transceiver **10**B that is transferred from the transceiver **10**B to an external processing device (not shown in FIG. **1**B) that provides additional processing of the imaging data.

[0047] FIG. **1**C is a side elevation view of an ultrasound transceiver **10**C that includes an inertial reference unit, according to still yet another embodiment of the invention. In this embodiment, the transceiver **10**C is configured to communicate signals through an interface cable **25**C to other external devices. For example, the signals communicated on the interface cable **25**C may include imaging data and/or positional information acquired by the transceiver **10**B that is transferred from the transceiver **10**B to an external processing device (not shown in FIG. **1**C) that provides additional processing of the imaging data. The interface cable **25**C may be configured to communicate data in accordance with any known or future data interface protocol. Consequently, the interface cable **25**C may be configured to communicate data using the known Universal Serial Bus protocol (USB), or using other known protocols, such as FIREWIRE, serial or even parallel port-configured cables. Alternatively, the interface cable **25**C may be a fiber optic cable that is operable to convey light-based signals.

[0048] FIG. **1**D is a side elevation view of an ultrasound transceiver **100** according to still another embodiment of the invention. The transceiver **10**D includes an inertial reference unit **27**A that is demountably coupled to one of the housing **18** or handle **12**, and that includes a positional sensing device such as the accelerometer **22** and/or an angular sensing device, such as the gyroscope **23**. The inertial reference unit as illustrated may have a collar configuration that circumscribes the housing **18**. Other demountable or detachable configurations are possible, for example, a slide-on tube detachably attachable to the handle **12**. The demountably couplable inertial reference unit **27**A is configured to be mounted on an ultrasound transceiver that does not have an inertial reference sensing capability. A wireless signal **25**D is emitted from the transceiver **10**D that includes acceleration and/or rate information generated by the accelerometer **22** and/or the gyroscope **23**. The foregoing accelerometer and rate information are routed from the inertial reference unit **27**A in the transceiver **10**D through corresponding electrical contacts between inertial reference unit **27**A and the housing **18**. Alternate embodiments of the transceiver **10**D include non-wireless signals conveyed through electrical cables and/or fiber optics, such as, for example, those previously described.

[0049] FIG. **1**E is side elevation view of an ultrasound transceiver **10**E according to another embodiment of the invention. The transceiver **10**E also includes an inertial reference unit **27**B that is detachably or demountably couplable to the housing **18**. The unit **27**B also optionally includes a wireless transmitter (not shown), and/or the accelerometer **22** and/or gyroscope **23**. The transceiver **10**E is shown with the detachably demountably couplable unit **27**B in a collar configuration that detachably demountably circumscribes the housing **18**. The collar **27**B similarly snaps onto a non-inertial reference transceiver and converts it to an inertial reference transceiver **10**E that suitably operates similar to transceiver **10**B of FIG. **1**B except that a wireless signal **25**E emanates from the collar **27**B. The wireless signal **25**E contains the positional information of the accelerometer **22** and/or gyroscope **23**. Other detachable or demountable configurations of the inertial reference unit **27**B are possible, for example, a slide-on tube demountably attachable to the handle **12**. Alternate embodiments of the transceiver **10**E include non-wireless signals conveyed through electrical cables and fiber optics previously described.

[0050] FIG. **2**A is a schematic illustration of the accelerometer of the transceivers **10**A-**10**E of FIGS. **1**A-**1**E, respectively. An accelerometer array **26** may be internally disposed within the accelerometer **22**. The array **26** is shown by dashed lines in FIG. **2**A, and includes elements that are generally oriented in mutually orthogonal directions. The accelerometer **26** may be oriented in any selected orientation with respect to the transceivers **10**A, **10**B and **10**C.

[0051] FIG. **2**B is an expansion of the schematic illustration of FIG. **2**A. The accelerometer array **26** includes an X-axis, Y-axis, and Z-axis oriented elements **26**X, **26**Y, and **26**Z, respectively. The accelerometer elements **26**X, **26**Y, and **26**Z are presented as a stacked array, although other configurations are possible. For example, a planar configuration may also be used. In either case, the X-axis, Y-axis, and Z-axis accelerometer elements **28**X, **28**Y, and **28**Z generate electrical signals that proportional to or otherwise indicative of accelerations along the respective X, Y, and Z-axes.

[0052] FIG. **3**A is a schematic illustration of the gyroscope of the transceivers **10**A-**10**E of FIGS. **1**A-**1**E, respectively. A gyroscope array **28** may be internally disposed within the gyroscope **23**. The array **28** is shown by dashed lines in FIG. **3**A, and includes elements that are generally oriented in mutually orthogonal directions. The gyroscope **23** may be oriented in any selected orientation with respect to the transceivers **10**A-**10**E.

[0053] FIG. **3**B is an expansion of the schematic illustration of FIG. **3**A. The gyroscope array **28** generally includes an X-axis, Y-axis, and Z-axis oriented elements **28**X, **28**Y, and **28**Z, respectively. The elements **26**X, **26**Y, and **26**Z are operable to sense motions about X, Y and Z axes, respectively, and generate electrical signals that are proportional to motions about the respective X, Y, and Z-axes.

[0054] FIG. **4** is a graphical representation of a plurality of three dimensional (3D) distributed scan lines emanating from a transceiver that cooperatively forms a scan cone **30**. Each of the scan lines have a length r that projects outwardly from the transceivers **10**A-**10**E of FIGS. **1**A-**1**E. As illustrated the transceiver **10**A emits 3D-distributed scan lines within the scan cone **30** that are one-dimensional ultrasound A-lines. The other transceiver embodiments **10**B-**10**E may also be configured to emit 3D-distributed scan lines. Taken as an aggregate, these 3D-distributed A-lines define the conical shape of the scan cone **30**. The ultrasound scan cone **30** extends outwardly from the dome **20** of the transceiver **10**A, **10**B and **10**C centered about an axis line **11**. The 3D-distributed scan lines of the scan cone **30** include a plurality of internal and peripheral scan lines that are distributed within a volume defined by a perimeter of the scan cone **30**. Accordingly, the peripheral scan lines **31**A-**31**F define an outer surface of the scan cone **30**, while the internal scan lines **34**A-**34**C are distributed between the respective peripheral scan lines **31**A-**31**F. Scan line **34**B is generally collinear with the axis **11**, and the scan cone **30** is generally and coaxially centered on the axis line **11**.

[0055] The locations of the internal and peripheral scan lines may be further defined by an angular spacing from the center scan line **34**B and between internal and peripheral scan lines. The angular spacing between scan line **34**B and peripheral or internal scan lines are designated by angle Φ and angular spacings between internal or peripheral scan lines are designated by angle Ø. The angles Φ_1, Φ_2, and Φ_3 respectively define the angular spacings from scan line **34**B to scan lines **34**A, **34**C, and **31**D. Similarly, angles $Ø_1$, $Ø_2$, and $\hbar_3$ respectively define the angular spacings between scan line **31**B and **31**C, **31**C and **34**A, and **31**D and **31**E.

[0056] With continued reference to FIG. **4**, the plurality of peripheral scan lines **31**A-E and the plurality of internal scan lines **34**A-D are three dimensionally distributed A-lines (scan lines) that are not necessarily confined within a scan plane, but instead may sweep throughout the internal regions and along the periphery of the scan cone **30**. Thus, a given point within the scan cone **30** may be identified by the coordinates r, Φ, and Ø whose values generally vary. The number and location of the internal scan lines emanating from the transceivers **10**A-**10**E may thus be distributed within the scan cone **30** at different positional coordinates as required to sufficiently visualize structures or images within a region of interest (ROI) in a patient. The angular movement of the ultrasound transducer within the transceiver **10**A-**10**E may be mechanically effected, and/or it may be electronically generated. In any case, the number of lines and the length of the lines may be uniform or otherwise vary, so that angle Φ sweeps through angles approximately between −60° between scan line **34**B and **31**A, and +60° between scan line **34**B and **31**B. Thus angle Φ in this example presents a total arc of approximately 120°. In one embodiment, the transceiver **10**A, **10**B and **10**C is configured to generate a plurality of 3D-distributed scan lines within the scan cone **30** having a length r of approximately 18 to 20 centimeters (cm).

[0057] FIG. **5**A is a graphical representation of a plurality of scan planes that form a three-dimensional (3D) array having a substantially conical shape. An ultrasound scan cone **40** formed by a rotational array of two-dimensional scan planes **42** projects outwardly from the dome **20** of the transceivers **10**A. The other transceiver embodiments **10**B-**10**E may also be configured to develop a scan cone **40** formed by a rotational array of two-dimensional scan planes **42**. The plurality of scan planes **40** are oriented about an axis **11** extending through the transceivers **10**A-**10**E. One or more, or preferably each of the scan planes **42** are positioned about the axis **11**, preferably, but not necessarily at a predetermined angular position θ. The scan planes **42** are mutually spaced apart by angles θ_1 and θ_2. Correspondingly, the scan lines within each of the scan planes **42** are spaced apart by angles ϕ_1 and ϕ_2. Although the angles θ_1 and θ_2 are depicted as approximately equal, it is understood that the angles θ_1 and θ_2 may have different values. Similarly, although the angles ϕ_1 and ϕ_2 are shown as approximately equal, the angles ϕ_1 and ϕ_2 may also have different angles. Other scan cone configurations are possible. For example, a wedge-shaped scan cone, or other similar shapes may be generated by the transceiver **10**A, **10**B and **10**C.

[0058] FIG. **5**B is a graphical representation of a scan plane **42**. The scan plane **42** includes the peripheral scan lines **44** and **46**, and an internal scan line **48** having a length r that extends outwardly from the transceivers **10**A-**10**E. Thus, a selected point along the peripheral scan lines **44** and **46** and the internal scan line **48** may be defined with reference to the distance r and angular coordinate values ϕ and θ. The length r preferably extends to approximately 18 to 20 centimeters (cm), although any length is possible. Particular embodiments include approximately seventy-seven scan lines **48** that extend outwardly from the dome **20**, although any number of scan lines is possible.

[0059] FIG. **5**C a graphical representation of a plurality of scan lines emanating from a hand-held ultrasound transceiver forming a single scan plane **42** extending through a cross-section of an internal bodily organ. The number and location of the internal scan lines emanating from the transceivers **10**A-**10**E within a given scan plane **42** may thus be distributed at different positional coordinates about the axis line **11** as required to sufficiently visualize structures or images within the scan plane **42**. As shown, four portions of an off-centered region-of-interest (ROI) are exhibited as irregular regions **49**. Three portions are viewable within the scan plane **42** in totality, and one is truncated by the peripheral scan line **44**.

[0060] As described above, the angular movement of the transducer may be mechanically effected and/or it may be electronically or otherwise generated. In either case, the number of lines **48** and the length of the lines may vary, so that the tilt angle ϕ sweeps through angles approximately between −60° and +60° for a total arc of approximately 120°. In one particular embodiment, the transceiver **10** is configured to generate approximately about seventy-seven scan lines between the first limiting scan line **44** and a second limiting scan line **46**. In another particular embodiment, each of the scan lines has a length of approximately about 18 to 20 centimeters (cm). The angular separation between adjacent scan lines **48** (FIG. **5**B) may be uniform or non-uniform. For example, and in another particular embodiment, the angular separation ϕ_1 and ϕ_2 (as shown in FIG. **5**C) may be about 1.5°. Alternately, and in another particular embodiment, the angular separation ϕ_1 and ϕ_2 may be a sequence wherein adjacent angles are ordered to include angles of 1.5°, 6.8°, 15.5°, 7.2°, and so on, where a 1.5° separation is between a first scan line and a second scan line, a 6.80 separation is between the second scan line and a third scan line, a 15.5° separation is between the third scan line and a fourth scan line, a 7.2° separation is between the fourth scan line and a fifth scan line, and so on. The angular separation between adjacent scan lines may also be a combination of uniform and non-uniform angular spacings, for example, a sequence of angles may be ordered to include 1.5°, 1.5°, 1.5°, 7.2°, 14.3°, 20.2°, 8.0°, 8.0°, 8.0°, 4.3°, 7.8°, and so on.

[0061] FIG. **5**D is an isometric view of an ultrasound scan cone that projects outwardly from the transceivers of FIGS. **1**A-E. Three-dimensional mages of a region of interest are presented within a scan cone **40** that comprises a plurality of 2D images formed in an array of scan planes **42**. A dome cutout **41** that is the complementary to the dome **20** of the transceivers **10**A-**10**E is shown at the top of the scan cone **40**.

[0062] FIG. **5**E is a top plan view of the scan cone **40** of FIG. **5**D. The arrangement of the scan planes **42** is shown symmetrically distributed or radiating from the cutout **41** and separated by an angle θ. The angle θ may vary so that the angular spacings may result in the scan cone **40** having an array of non-symmetrically distributed scan planes.

[0063] FIG. **6** and FIG. **7** are respective isometric views of a transceiver **10**A having an inertial reference unit, according to an embodiment of the invention. With reference to FIG. **6**, the transceiver **10**A is received by a support cradle **50**A. The cradle **50**A is structured to perform various support functions that assist the transceiver **10**A. For example, the support cradle **50**A may be configured to exchange wireless signals **50**A-**2** with other devices, such as an external processor. The support cradle **50**A may also include a battery charger that is operable to charge an internal battery that is positioned within the transceiver **10**A. With reference now to FIG. **7**, the transceiver **10**B is received by a support cradle **50**B that includes an interface unit that is operable to receive ultrasound and/or positional information from the transceiver **10**A, and optionally to format the information according to a suitable data interface protocol. Accordingly, the cradle **50** includes an interface cable **50**B-**2** that is configured to exchange the formatted information with an external device.

[0064] FIG. **8** is an isometric view of an inertial ultrasound imaging system **60**A according to another embodiment of the invention. The system **60**A includes the transceiver **10**B of FIG. **1**B, although the transceiver **10**C of FIG. **1**C may also be used without significant modification. The system **60**A also includes a personal computing device **52** that is configured to wirelessly exchange information with the transceiver **10**B. Any means of information exchange can be employed when the transceiver **10**C is used. In operation, the transceiver **10**B is applied to a side abdominal region of a patient **68**. The transceiver **10**B is placed off-center from a centerline **68**C of the patient **68** to obtain, for example a trans-abdominal image of a uterine organ in a female patient. The transceiver **10**B may contact the patient **68** through a pad **67** that includes an acoustic coupling gel that is placed on the patient **68** substantially left of the umbilicus **68**A and centerline **68**C. Alternatively, an acoustic coupling gel may be applied to the skin of the patient **68**. The pad **67** advantageously minimizes ultrasound attenuation between the patient **68** and the transceiver **10**B by maximizing sound conduction from the transceiver **10**B into the patient **68**.

[0065] Wireless signals **25**B-**1** contain echo information that is conveyed to and processed by the image processing algorithm in the personal computer device **52**. A scan cone **40**A displays an internal organ as partial image **56**A on a computer display **54**. The image **56**A is significantly truncated and off-centered relative to a middle portion of the scan cone **40**A due to the positioning of the transceiver **10**B.

[0066] As shown in FIG. **8**, the trans-abdominally acquired image is initially obtained during a targeting phase of the imaging. The transceiver **10**B is operated in a two-dimensional continuous acquisition mode. In the two-dimensional continuous mode, data is continuously acquired and presented as a scan plane image as previously shown and described. The data thus acquired may be viewed on a display device, such as the display **54**, coupled to the transceiver **10**B while an operator physically translates the transceiver **10**B across the abdominal region of the patient. When it is desired to acquire data, the operator may acquire data by depressing the trigger **14** of the transceiver **10**B to acquire real-time imaging that is presented to the operator on the display device. If the initial location of the transceiver is significantly off-center, in this case only a portion of the organ **56** is visible in the scan plane **40**A.

[0067] FIG. **9** is an isometric view of an inertial ultrasound imaging system **60**A according to another embodiment of the invention. The system **60**A includes the transceiver of FIG. 1B and is applied to a center abdominal region of a patient. The transceiver **10**B may be freehand translated to a position beneath the umbilicus **68**A on the centerline **68**C of the patient **68**. Wireless signals **25**B-**2** having information from the transceiver **10**B is communicated to the personal computer device **52**. The inertial reference unit positioned within the transceiver **10**B senses positional changes for the transceiver **10**B relative to a reference coordinate system. Information from the inertial reference unit, as described in greater detail below, permits updated real-time scan cone image acquisition, so that a scan cone **40**B having a complete image of the organ **56**B can be obtained. Still other embodiments are within the scope of the present invention. For example, the transceiver **10**C of FIG. **1**C may also be used in the system **60**A, as shown in FIG. **10**. The transceiver **10**A and the support cradle **50**A shown in FIG. **6** as well as the transceiver **10**A and the support cradle **50**B may also be used, as shown in FIG. **11** and FIG. **12**, respectively.

[0068] FIG. **13** is a partial isometric view of an ultrasound system **100** according to another embodiment of the invention. The system **100** includes one or more personal computer devices **52** that are coupled to a server **56** by a communications system **55**. The devices **52** are, in turn, coupled to one or more ultrasound transceivers, for examples the systems **60**A-**60**D. The server **56** may be operable to provide additional processing of ultrasound information, or it may be coupled to still other servers (not shown in FIG. **13**) and devices, for examples transceivers **10**D and **10**E having snap on collars **27**A and **27**B respectively.

[0069] FIG. **14** is a schematic illustration of the Internet in communication with the inertial ultrasound imaging systems of FIGS. **9**-**12**. An Internet system **110** is coupled or otherwise in communication with the systems **60**A-**60**D. The system **110** may also be in communication with the transceivers **10**D and **10**E.

[0070] FIG. **15**A is a schematic illustration of inertial reference coordinates superimposed over a transceiver experiencing translation changes between two transceiver locations regions. The transceiver locations provide different ultrasound probe views of a patient's ROI via the transceivers **10**A-**10**E. Referring now to transceiver **10**A, but not excluding the other transceivers **10**B-**10**E embodiments previously described, freehand translations of the transceiver **10**A will cause changes in at least one Cartesian coordinate axis value. Changes of either X, Y, or Z locations, or possibly any combination thereof depending on the user's repositioning of the transceiver **10**A and whether or not there is only a single or multiple axis translation from the first to the second freehand positions can occur. As shown in this illustration, translation only is shown in that there is an absence of rotation or tilt of the transceiver **10**A. The first freehand position Cartesian axes and designated as X-Y-Z and the second Cartesian axes are designated as X'-Y'-Z'. The respective differences due to translation for each axis are designated as translation values T_x, T_y, and T_z.

[0071] FIG. **15**B further describes schematically the translation movements from an initial or first freehand position **150** overlaid on an X-Y Cartesian plot. The dashed curved arrows indicate the freehand movement path to positional points from the initial freehand position **150**. As earlier described, the transceiver **10**A may be positioned in various positions relative to a patient, so that different two-dimensional views of a desired anatomical region of interest may be generated. Accordingly, the transceiver **10**A (as shown in FIG. **1**A) may be positioned at the first transceiver or initial position **150**, whereupon the inertial reference unit (as shown in FIG. **1**) is aligned, so that the position **150** may be used as an origin for the various freehand positions. As illustrated, the initial position point **150** is located at the X-Y-Z axes origin and may be conveniently defined by a component set of (0, 0, 0). All subsequent positional movements may then be referenced to the initial position **150**. The first transceiver position **150** may include a positional location that is proximate to a desired anatomical portion of the patient, or it may include a positional location that is spaced apart from the patient. In either case, the transceiver **10**A may be moved to still other locations, such as a second transceiver position **152**, a third transceiver position **154**, and a fourth transceiver position **156**, although though other positional locations relative to the first transceiver position **150** may also be used. As illustrated, transceiver locations **152**, **154** and **156** reside in the first Cartesian quadrant, though any transceiver location may be within other Cartesian quadrants or occupy a Cartesian axis. Respective coordinates for each of the vectors **P1**, **P2**, and **P3** respectively extending to the second position **152**, the third position **154** and the fourth position **156** and may be readily expressed as vector components in the form of T_{xi}, T_{yi}, and T_{zi} where i corresponds to a selected one of the vectors. Accordingly, vector **P1** from the initial component set to the second position point **152** is defined by component set (T_{x1}, T_{y1}, and T_{z1}) derived from positional information obtained from the accelerometer **22**. Similarly, movement to the third positional point **154** is described by vector **P2** having a component set (T_{x2}, T_{y2}, and T_{z2}). Thereafter, movement to the fourth positional point **156** is described by vector **P3** having a component set (T_{x3}, T_{y3}, and T_{z3}).

[0072] FIG. **16**A is a schematic illustration of inertial reference coordinates superimposed over a transceiver experiencing rotation and tilt changes between two transceiver locations regions. The transceiver locations provide different translational and/or rotational ultrasound probe views of a patient's ROI. Freehand translations of the transceiver **10**A will cause changes in at least one Cartesian coordinate axis value previously described, and whether or not there is any tilt or rotation of the transceiver **10**A between an initial and succeeding freehand positioning. Thus a change in location of a given point P of an ROI can be defined in Cartesian terms with angular values. By way of example, a solid lined X-Y-Z Cartesian axis overlaid upon the transceiver **20** in the first freehand position is compared to a dashed lined X'-Y'-Z' Cartesian axis overlaid upon the transceiver **20** in the second freehand position. Changes in translation values of the X and Y-axes are shown as angular displacements γ and β, respectively. Similarly, changes in rotation about the Z-axis are angle values α. Thus changes between X of the first freehand position and X' of the second freehand position are defined by angle γ, Y of the first freehand position and Y' of the second freehand position are defined by angle β, and Z of the first freehand position and Z' of the second freehand position are defined by angle α. The accelerometer array **26** and the gyroscope array **28** cooperatively determined the changes in angular displacements α, β, and γ through their respective X, Y, and Z-axis specific accelerometers and gyroscopes as illustrated in FIGS. **2**B and **3**B.

[0073] FIG. **16**B is a schematic illustration that will be used to further describe the method of FIG. **16**A involving a series of translation and rotation movements from an initial free-hand position. The angular positions of the transceiver **10**A may also be determined that are relative to the first transceiver position **150**. Beginning with the inertial reference unit (as shown in FIG. **1**) at position **150**, a series of motions having translation and rotation results in a second transceiver position **162**, a third transceiver position **164**, and a fourth transceiver position **166**. The second transceiver position is located in the fourth Cartesian quadrant and the third and fourth transceiver positions **164** and **166** are located within the first Cartesian quadrant. Respective coordinates for each of the vectors P**4**, P**5**, and P**6** extending to the second position **162**, the third position **164** and the fourth position **166**, may respectively be readily defined as translation point sets in the form of T_{xi}, T_{yi}, and T_{zi} and angle β. For example, the second transceiver position **162** may include a first rotational angle β_1, while the third transceiver position **164** and the fourth transceiver position **166** include second and third rotational angles, β_2 and β_3, respectively. Accordingly, vector P4 from the initial position **150** to the second position point **162** is defined by point set (T_{x1}, T_{y1}, and T_{z1}) derived from positional information obtained from the accelerometer **22** and angle β_1 positional information obtained from the gyroscope **23**. Similarly, movement to the third positional point **154**B is described by vector P2B having a point set (T_{x2}, T_{y2}, and T_{z2}) and angle β_2. Thereafter, movement to the fourth positional point **156**B is described by vector P3B having a point set (T_{x3}, T_{y3}, and T_{z3}) and angle β_3. Although FIG. **16**B shows the first rotational angle β_1, the second rotational angle β_2, and the third rotational angle β_3 positioned in one plane, it is understood that rotational angles also generally exist in other rotational planes.

[0074] The positional coordinates and angles that are determined relative to the first position **150** may be used to combine the two-dimensional images determined at each of the positions into a three-dimensional ultrasound image. Although FIGS. **15**A and **15**B describes a translational movement of the transceiver **10**A relative to the first position **150**, and FIGS. **16**A and **16**B describes rotations of the transceiver **10**A relative to the position **150**, it is understood that successive movements of the transceiver **10**A generally include both translational movements and rotations of the transceiver **10**A.

[0075] FIG. **17** is a flowchart that will be used to describe a method **200** of forming a three dimensional ultrasound image, according to an embodiment of the invention. At block **202**, an initial position for an ultrasound transceiver is selected, and an inertial reference unit associated with the ultrasound transceiver is aligned at the initial position. At block **204**, ultrasound image information is acquired at the initial position, and the ultrasound image is viewed. Thereafter, at decision diamond **206**, an answer to the query "Is image acceptable?" is determined. Based upon a review of the image obtained at block **204**, if it is determined that the initial position selected at block **202** is unsatisfactory, that is, the answer is "No", a new initial position may be selected by cycling back to block **202**. If the answer is "Yes", that is, the initial position is satisfactory, additional ultrasound may be acquired at other positional locations, as shown at block **208**. While the transceiver is moved to the other positional locations, acceleration and angular rate information is integrated along the motion path. At block **210**, the ultrasound and positional information acquired at the initial and at the other additional locations is integrated to generate one or more three-dimensional images, which may be visually examined. Then, at decision block **212**, if the one or more ultrasound images are determined to be unsatisfactory, then the method **200** returns to block **208**, whereupon different and/or additional ultrasound information may be acquired. If the ultrasound image is determined to be acceptable, the method **200** ends, as also shown by exciting method **200** via the affirmative route from decision block **212**. In alternate embodiments one or more of the foregoing method steps are omitted. In other embodiments, additional steps may be included.

[0076] FIG. **18** is flowchart that will be used to further describe the method **200** of FIG. **17**. In particular, FIG. **18** will be used to describe a method **214** of determining a position of an ultrasound transceiver, according to another embodiment of the invention. The method **200** includes blocks **214-4** and **214-14**, which may be simultaneously executed, or independently executed. In general, however, it understood that motions of the transceiver relative to a patient include translations and rotations of the transceiver relative to the initial location. At block **214-4**, translational signals from an accelerometer portion of the inertial reference unit are sampled at an initial position N_i. At block **214-6**, the transceiver is moved to another position N_{i+1}, and translational signals are continuously or intermittently sampled from the accelerometer portion as the transceiver is moved from the position N_i to the position N_{i+1}. At block **214-8**, a translational vector T is calculated for the positional location N_{i+1} by integrating the translational signals. At block **214-14**, rotational rate signals obtained from the inertial reference unit are sampled at the position N_i. At block **214-16**, the transceiver is moved, and rotational rate signals are again continuously sampled as the transceiver is moved to the position N_{i+1}. The rotational rate signals are integrated as the transceiver is moved so that rotational angles for the transceiver may be generated. Accordingly, at block **214-18**, respective rotational transformation matrices $R_x(\alpha)$, $R_y(\beta)$ and $R_z(\gamma)$ are calculated based upon the generated rotational angles as follows:

$$R_x(\alpha) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha & \sin\alpha \\ 0 & -\sin\alpha & \cos\alpha \end{bmatrix}$$

$$R_y(\beta) = \begin{bmatrix} \cos\beta & 0 & -\sin\beta \\ 0 & 1 & 0 \\ \sin\beta & 0 & \cos\beta \end{bmatrix}$$

$$R_z(\gamma) = \begin{bmatrix} \cos\gamma & \sin\gamma & 0 \\ -\sin\gamma & \cos\gamma & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

[0077] A three-dimensional rotational matrix R may then be calculated by forming a product of the rotational transformation matrices $R_x(\alpha)$, $R_y(\beta)$ and $R_z(\gamma)$ so that $R=R_x(\alpha)\times R_y(\beta)\times R_z(\gamma)$. At block **214-24**, the translational vector T and the rotational matrix R obtained from block **214-8** and block **214-18**, respectively, are combined so that a positional vector P may be defined for the transceiver, so that $P_{i+1}=RP_i+T$. In alternate embodiments one or more of the foregoing method steps are omitted. In other embodiments, additional steps may be included.

[0078] While the preferred embodiment of the invention has been illustrated and described, as noted above, many changes can be made without departing from the spirit and scope of the invention. For example, other uses of the invention include determining the areas and volumes of the prostate, heart, bladder, and other organs and body regions of clinical interest as the images are updated by the ultrasound inertial reference system. Accordingly, the scope of the invention is not limited by the disclosure of the preferred embodiment.

We claim:

1. An ultrasound imaging system, comprising:

an ultrasound unit configured to ultrasonically scan at least one plane within a region of interest in a subject and generate imaging information from the scan;

an inertial reference unit configured to detect relative position of the ultrasound unit, during at least one scan of at least one plane; and

a processing unit configured to receive the imaging information and the detected corresponding relative positions and,

based on the received imaging information and relative position, operable to generate at least one image of the region of interest.

2. The imaging system of claim **1**, wherein the inertial reference unit further comprises a first device that is configured to sense an acceleration of the ultrasound unit, and a second device that is configured to detect an angular rate of rotation of the ultrasound unit.

3. The imaging system of claim **2**, wherein the first device includes an accelerometer that is responsive to at least one acceleration in a selected direction, and further wherein the second device is responsive to at least one angular rate of rotation about a selected axis.

4. The imaging system of claim **1**, wherein the inertial reference unit is fixedly coupled to the ultrasound unit.

5. The imaging system of claim **1**, wherein the inertial reference unit is removably coupled to the ultrasound unit.

6. The imaging system of claim **1**, wherein the ultrasound unit further comprises a plurality of elements that are configured to be selectively excited to scan a plane within the region of interest.

7. The imaging system of claim **1**, wherein the ultrasound unit further comprises an actuator coupled to an array of piezoelectric elements that is configured to rotate the array about a selected axis.

8. The imaging system of claim **1**, wherein the processing unit is a mainframe processor that is spaced apart from the ultrasound unit.

9. The imaging system of claim **1**, wherein at least the processing unit and the ultrasound are incorporated in a common unit.

10. The imaging system of claim **1**, wherein the inertial reference unit further comprises a micro-electromechanical system (MEMs) based inertial reference unit.

11. A method of imaging a bodily portion in a subject, comprising:

ultrasonically scanning a first selected plane in the subject using an ultrasound scanning device to generate a first planar ultrasound data set;

determining a position of the first selected plane by accessing an inertial reference unit coupled to the ultrasound scanning device;

ultrasonically scanning a second selected plane in the subject to generate a second planar ultrasound data set;

determining a position of the second selected plane; and

processing the first data set and the position of the first selected plane and the second data set and the position of the second selected plane to generate a three-dimensional image of the bodily portion.

12. The method of claim **11**, wherein determining a position further comprises determining at least one of an acceleration and an angular rate of rotation of the ultrasound scanning device.

13. The method of claim **12**, wherein processing the first data set and the position of the first selected plane and the second data set and the position of the second selected plane further comprises integrating the at least one of an acceleration and an angular rate of rotation of the ultrasound scanning device.

14. The method of claim **11**, wherein determining a position of the first selected plane further comprises aligning the inertial reference unit to establish a first reference position.

15. The method of claim **14**, wherein aligning the inertial reference unit to establish a first reference position further comprises establishing an origin for the ultrasound scans.

16. A ultrasound system configured for hand held operation, comprising:

an ultrasound transceiver having an outwardly extending handle suitably configured to permit a user to manipulate the transceiver relative to a subject;

an inertial reference unit coupled to the transceiver that is operable to determine selected positions of the transceiver as it is moved; and

a processing unit coupled to the ultrasound transceiver and the inertial reference unit that is configured to process ultrasound data acquired from the subject and to process positional data and generate an ultrasound image therefrom.

17. The system of claim **16**, wherein the inertial reference unit is removably coupled to the ultrasound transceiver.

18. The system of claim **16**, wherein the processing unit is configured to receive planar ultrasound scans from the ultrasound transceiver and corresponding positional data from the inertial reference unit and generate a three dimensional ultrasound image.

19. The system of claim **16**, wherein the ultrasound transceiver further comprises a suitable data interface that permits ultrasound data to be communicated to the processing unit.

20. The system of claim **19**, wherein the data interface includes one of a universal serial bus (USB) and a FIREWIRE interface.

21. The system of claim **19**, wherein the data interface includes a wireless data interface.

22. The system of **19**, further comprising a cradle configured to receive the transceiver, further wherein the cradle includes the data interface.

* * * * *

patsnap

专利名称(译)	使用惯性参考单元的超声成像系统和方法		
公开(公告)号	US20080262356A1	公开(公告)日	2008-10-23
申请号	US11/925905	申请日	2007-10-27
[标]申请(专利权)人(译)	CHALANA VIKRAM MCMORROW GERALD YUK JONGTAE		
申请(专利权)人(译)	CHALANA VIKRAM MCMORROW GERALD YUK JONGTAE		
当前申请(专利权)人(译)	CHALANA VIKRAM MCMORROW GERALD YUK JONGTAE		
[标]发明人	CHALANA VIKRAM MCMORROW GERALD YUK JONGTAE		
发明人	CHALANA, VIKRAM MCMORROW, GERALD YUK, JONGTAE		
IPC分类号	A61B8/13		
CPC分类号	A61B8/08 A61B8/4254 A61B8/4281 A61B8/4455 A61B8/4461 A61B8/4472 A61B8/4483 A61B8/483 A61B2560/0456 A61B2562/028 G01S7/5205 G01S15/8936		
优先权	60/621349 2004-10-22 US 60/608426 2004-09-09 US 60/400624 2002-08-02 US 1020020083525 2002-12-24 KR 60/423881 2002-11-05 US 60/609184 2004-09-10 US		
外部链接	Espacenet USPTO		

摘要(译)

公开了使用惯性参考单元进行超声成像的系统和方法。在一个实施例中，超声成像系统包括超声单元，该超声单元被配置为超声扫描对象中的感兴趣区域内的至少一个平面并从扫描生成成像信息。提供惯性参考单元，其在超声单元扫描多个平面时检测超声单元的相对位置。处理单元被配置为接收成像信息和对应的检测位置，并且可操作以生成感兴趣区域的图像。