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(54) **METHOD AND APPARATUS FOR AUTOMATIC OPTIMIZATION OF SCANNING PARAMETERS FOR ULTRASOUND IMAGING**

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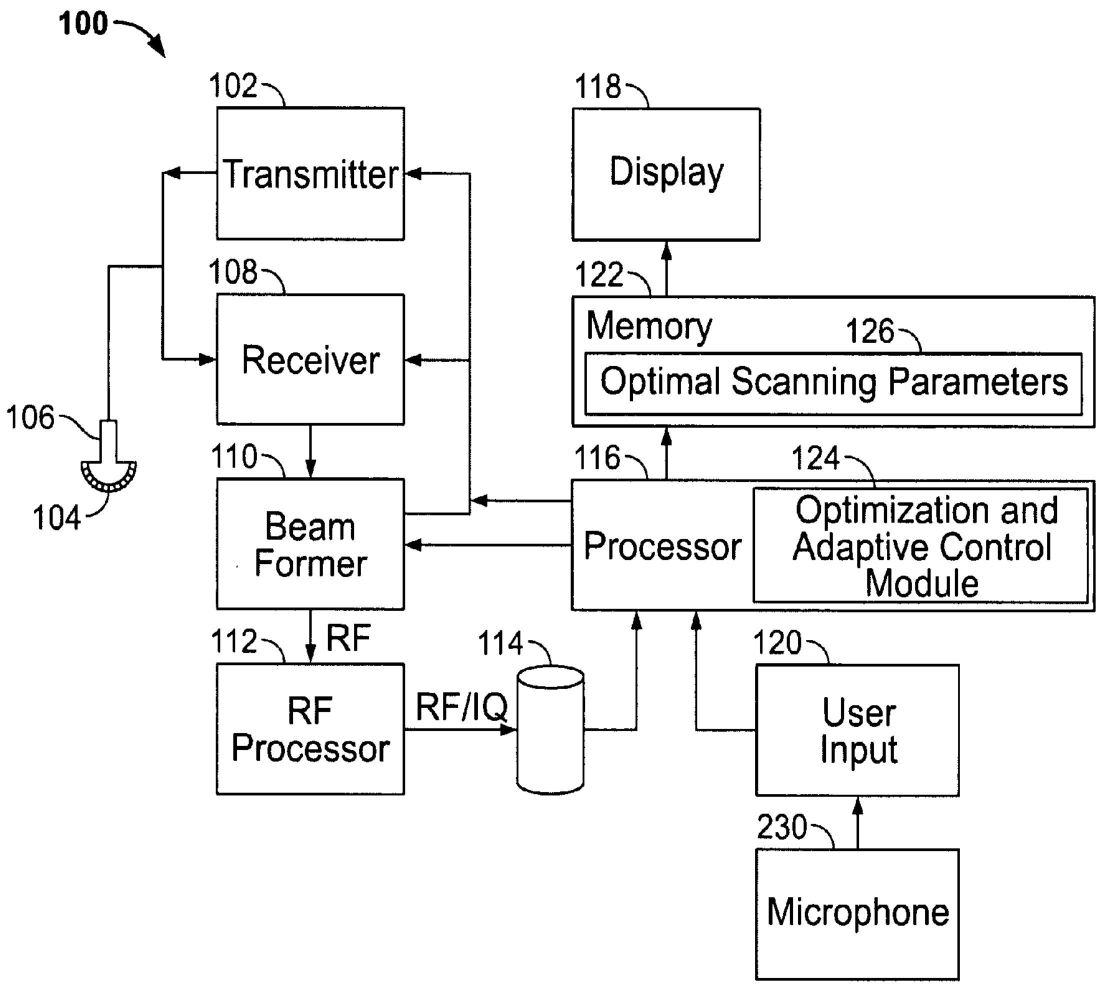
(57) **ABSTRACT**

An ultrasonic probe has transducer elements for transmitting and receiving ultrasound signals to form an ultrasound image. An optimization module receives a first scanning depth based on the ultrasound image and determines a first transmit pattern and receive filter settings based on the first scanning depth. The first transmit pattern and the receive filter settings are used to acquire the ultrasound image. Transmit and receive circuitry transmit and receive the ultrasound signals based on the first transmit pattern



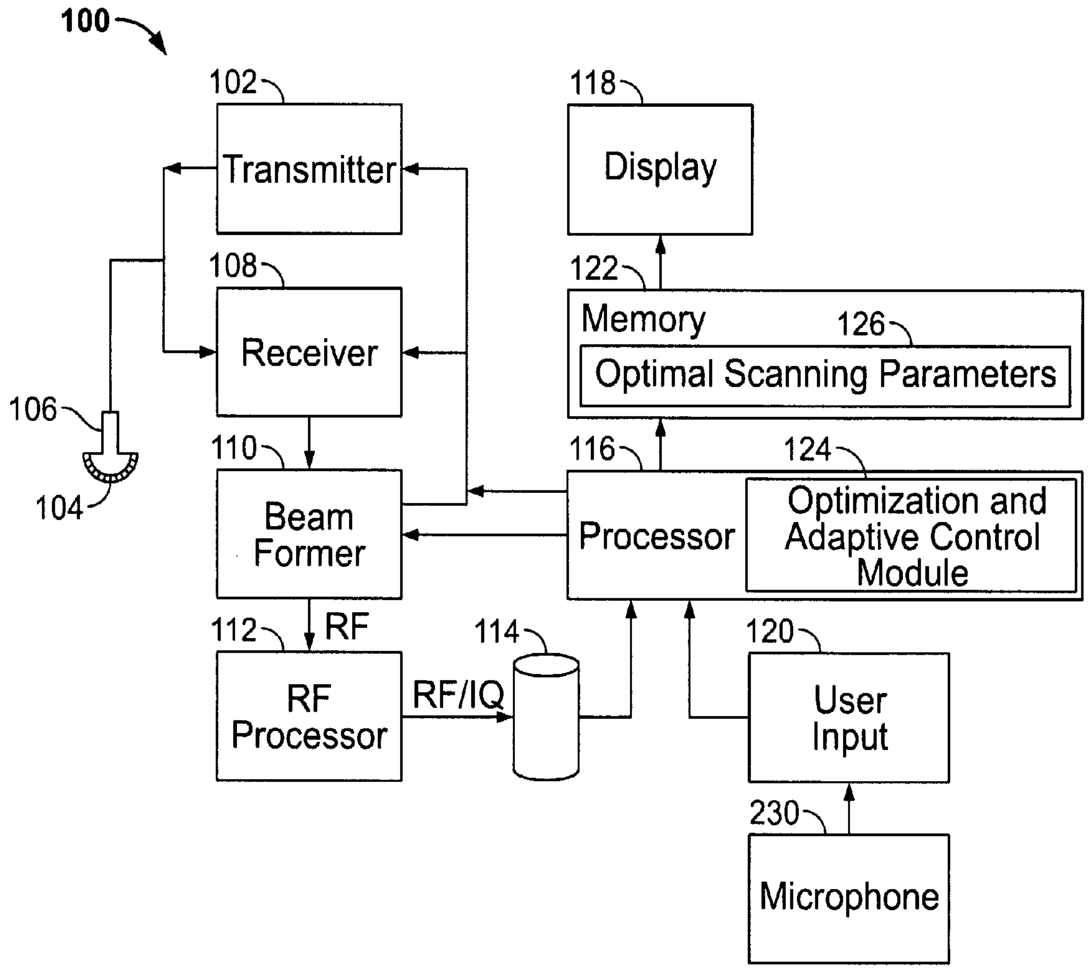

100
102
Transmitter
118
Display
108
Receiver
122
Memory
126
Optimal Scanning Parameters
106
104
110
Beam Former
116
124
Processor
Optimization and Adaptive Control Module
112
RF
114
120
RF Processor
RF/IQ
User Input
230
Microphone

FIG. 1

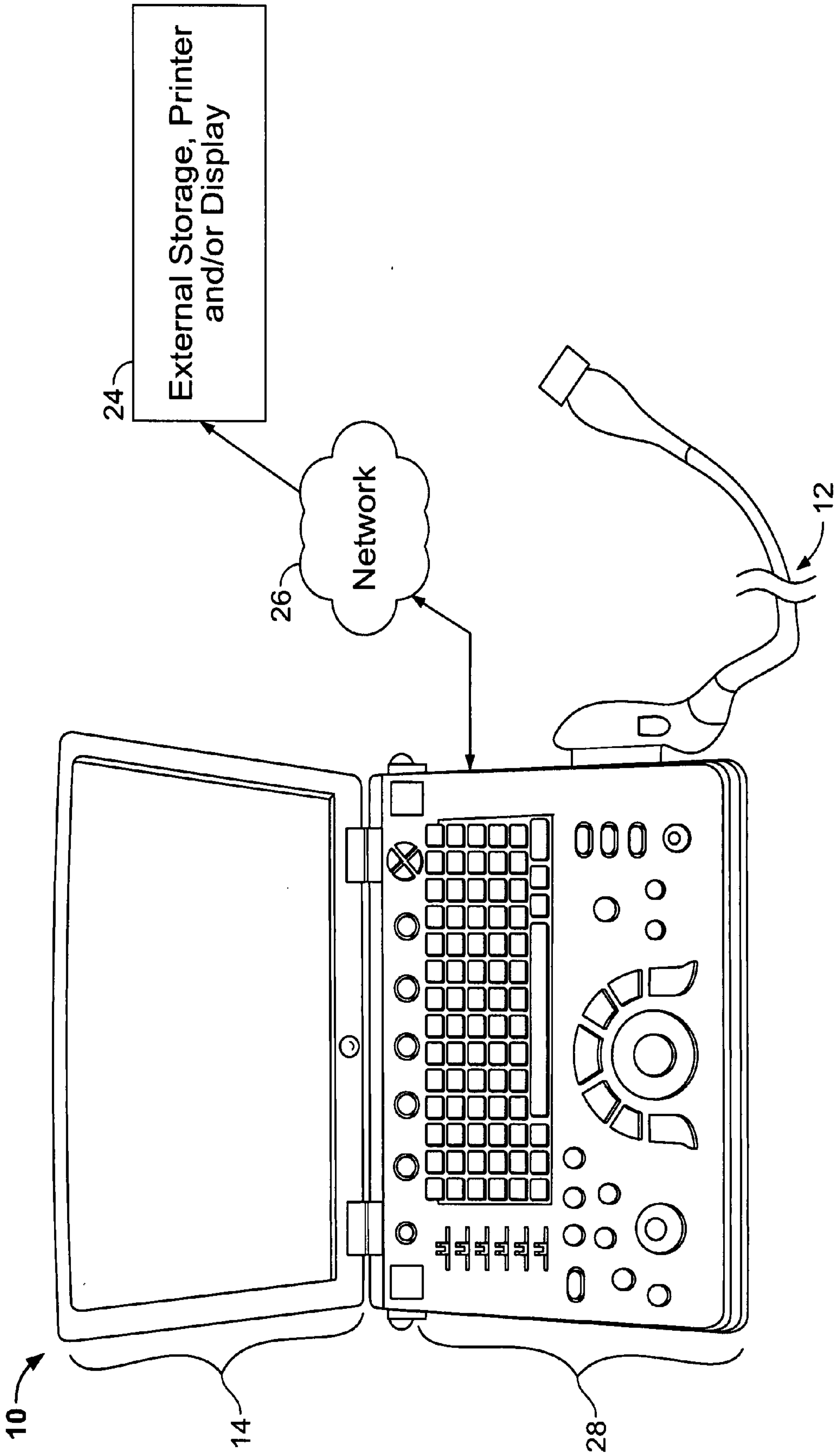

External Storage, Printer and/or Display
24
Network
26
12
10
14
28

FIG. 2

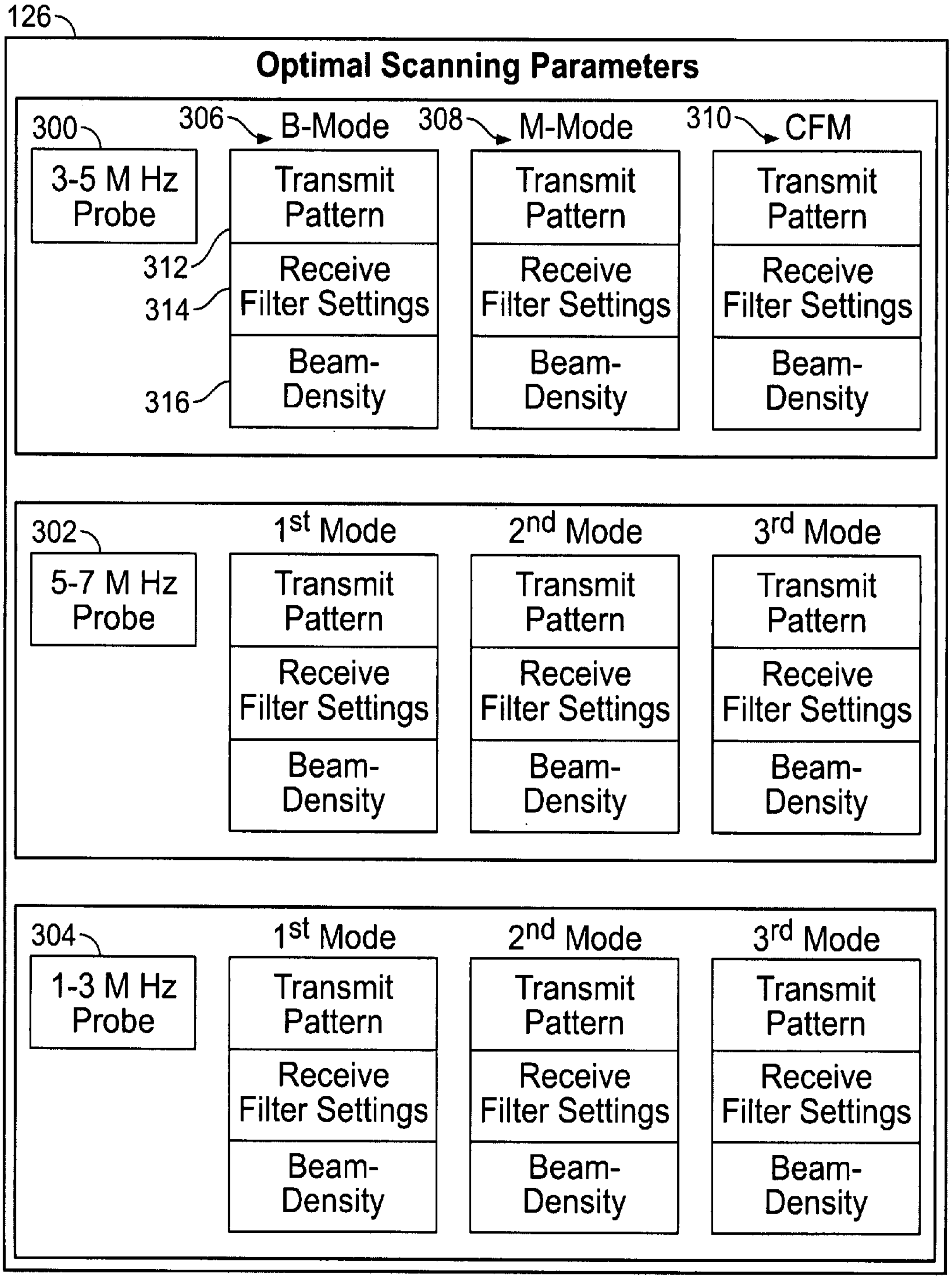

126
Optimal Scanning Parameters
300
3-5 M Hz Probe
306
B-Mode
308
M-Mode
310
CFM
Transmit Pattern
Receive Filter Settings
Beam-Density
312
314
316
302
5-7 M Hz Probe
1st Mode
2nd Mode
3rd Mode
304
1-3 M Hz Probe

FIG. 3

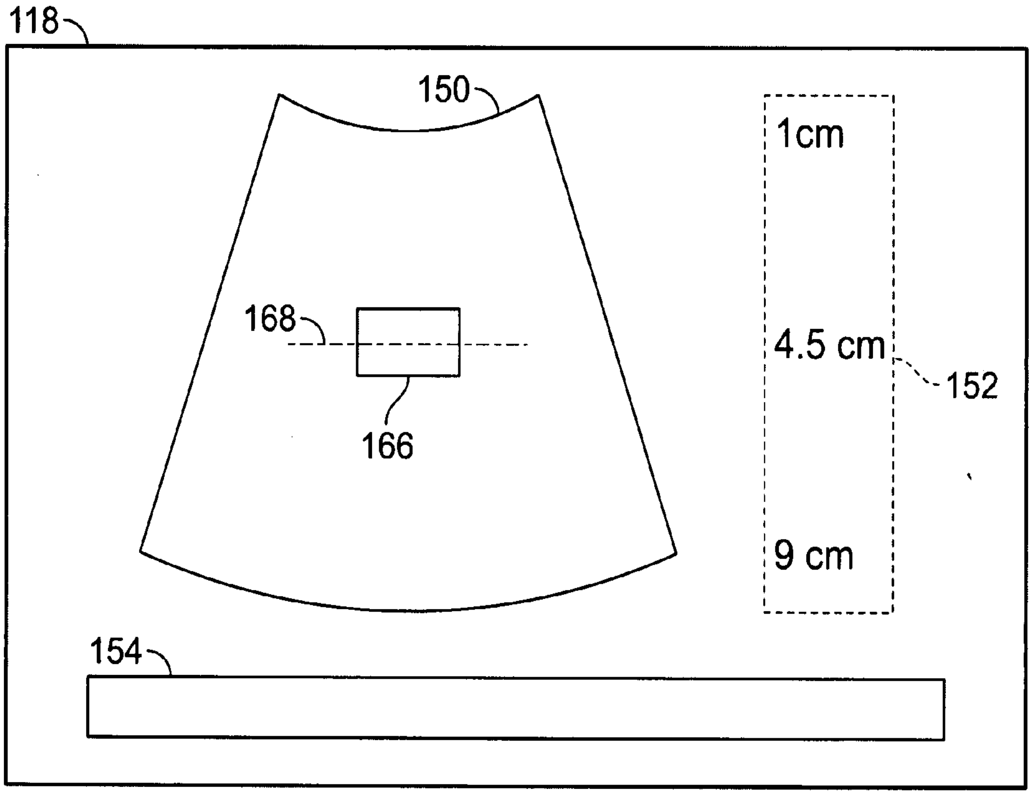

118
150
1cm
168
4.5 cm
152
166
9 cm
154

FIG. 4

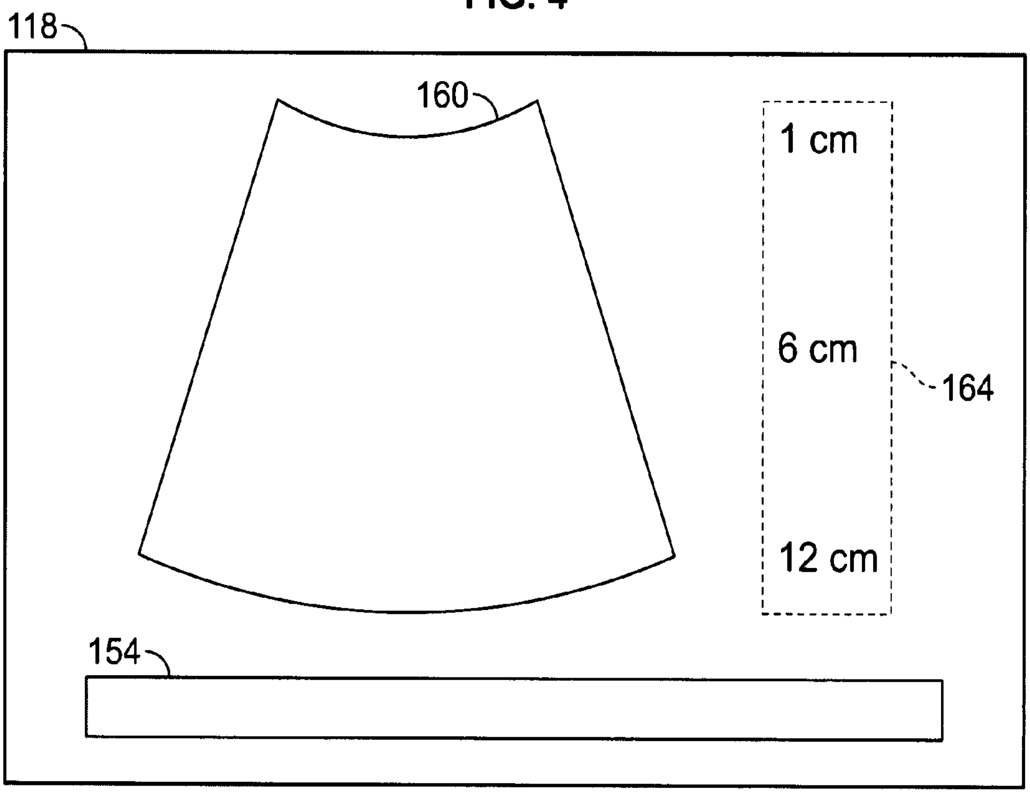

118
160
1 cm
6 cm
164
12 cm
154

FIG. 5

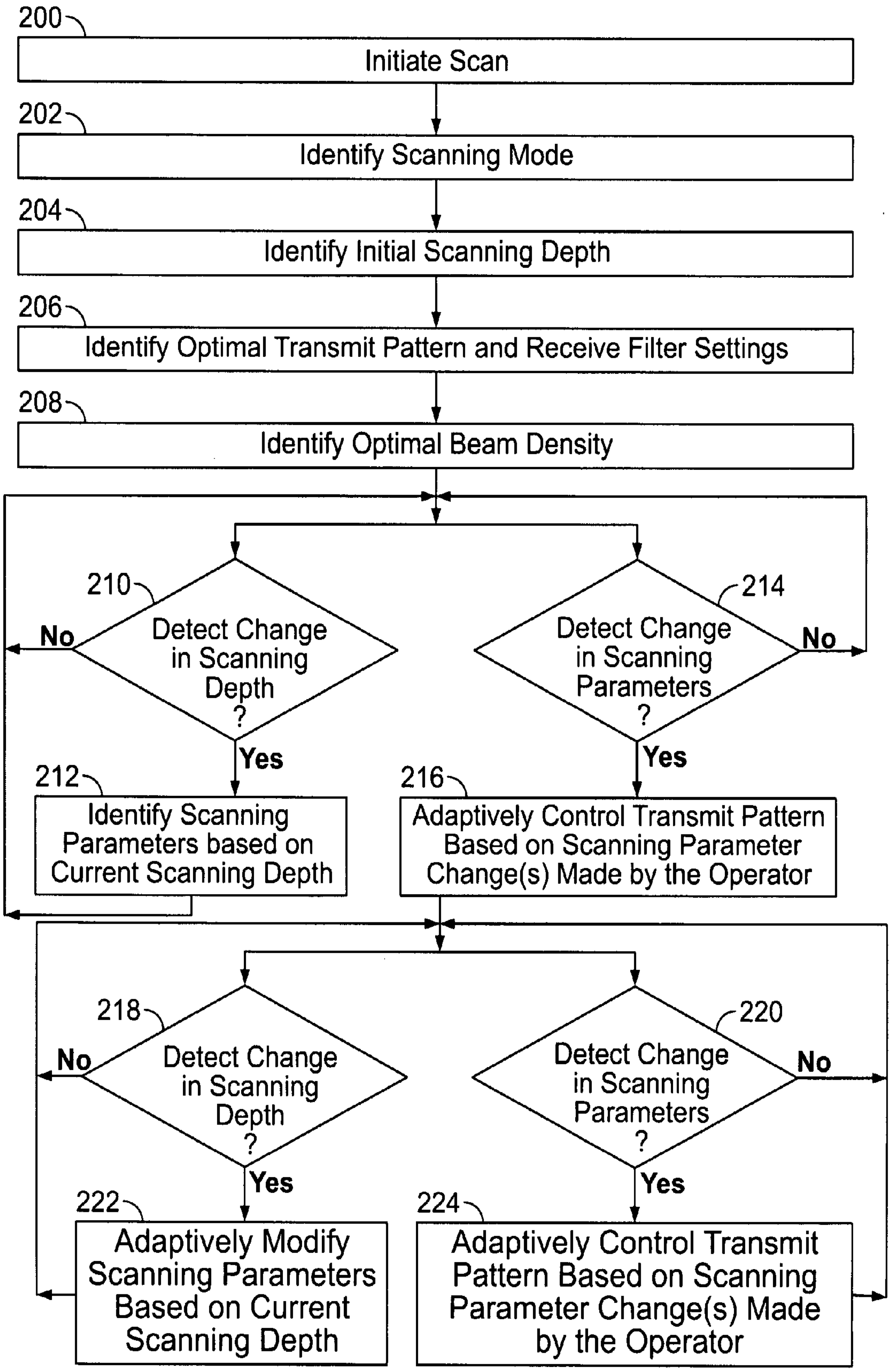
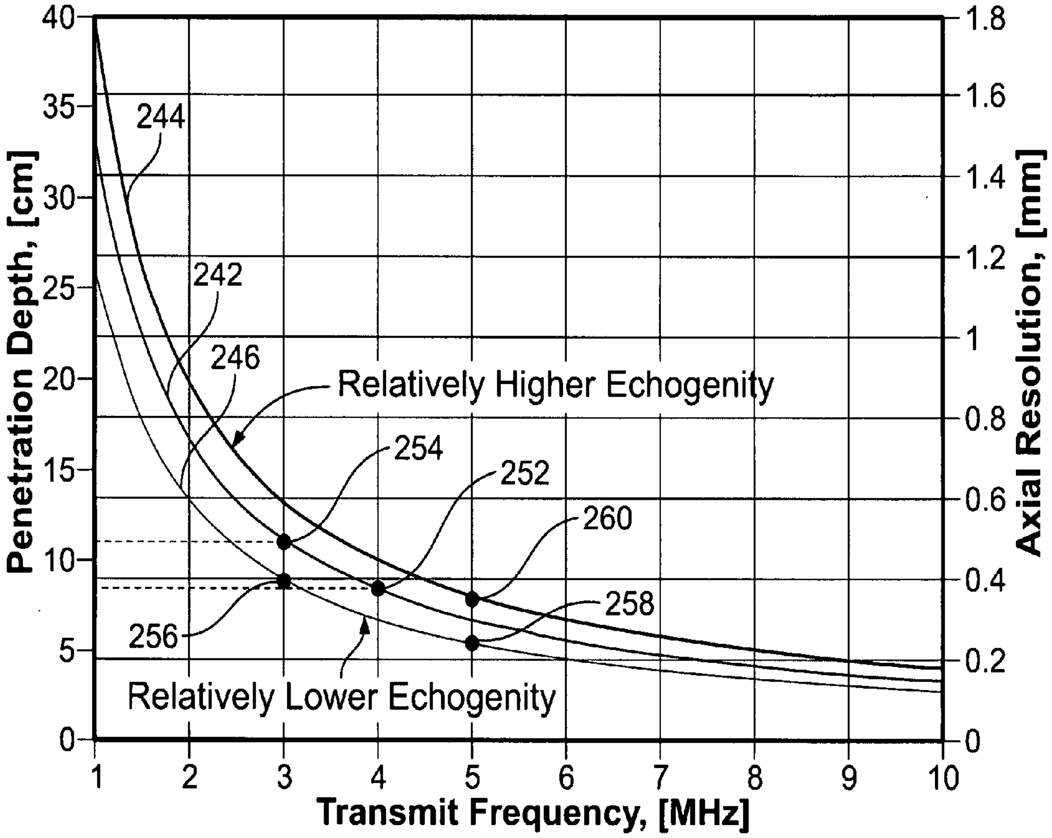

200
Initiate Scan
202
Identify Scanning Mode
204
Identify Initial Scanning Depth
206
Identify Optimal Transmit Pattern and Receive Filter Settings
208
Identify Optimal Beam Density
210
Detect Change in Scanning Depth ?
No
Yes
212
Identify Scanning Parameters based on Current Scanning Depth
214
Detect Change in Scanning Parameters ?
No
Yes
216
Adaptively Control Transmit Pattern Based on Scanning Parameter Change(s) Made by the Operator
218
Detect Change in Scanning Depth ?
No
Yes
222
Adaptively Modify Scanning Parameters Based on Current Scanning Depth
220
Detect Change in Scanning Parameters ?
No
Yes
224
Adaptively Control Transmit Pattern Based on Scanning Parameter Change(s) Made by the Operator

FIG. 6



40
35
30
25
20
15
10
5
0
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Penetration Depth, [cm]
Axial Resolution, [mm]
244
242
246
254
252
260
258
256
Relatively Higher Echogenity
Relatively Lower Echogenity
1
2
3
4
5
6
7
8
9
10
Transmit Frequency, [MHz]

FIG. 7

METHOD AND APPARATUS FOR AUTOMATIC OPTIMIZATION OF SCANNING PARAMETERS FOR ULTRASOUND IMAGING

BACKGROUND OF THE INVENTION

[0001] This invention relates generally to ultrasound imaging, and more particularly, to automatically optimizing scanning parameters.

[0002] Resolution and penetration are two main measures of quality in ultrasound imaging. Ultrasound spatial resolution is defined as the minimum distance at which two adjacent reflecting objects can be distinguished. Spatial resolution can be improved, in general, by increasing transmit frequency and beam-density. Ultrasound penetration is defined as the maximum depth from which usable signals return to the transducer. The penetration depth can be increased to view deeper structures by decreasing the transmit frequency. Therefore, the choice of frequency is a trade-off between the image spatial resolution and the penetration depth.

[0003] An operator may also change the beam-density, which is a trade-off between frame-rate and lateral resolution. Increasing the beam-density increases the lateral resolution up to an upper limit level that is a function of beam-width and pixel density of the display-raster of a display used to display the ultrasound image.

[0004] Currently, broadband ultrasound probes are available that provide a wide spectrum of transmit frequencies within a single probe. Thus, the same probe may be used to image a wide range of patients and/or anatomical structures. During an ultrasound examination, the operator has to balance the technical compromise of resolution versus penetration. An operator often begins a routine scanning procedure by visualizing structures that lie proximal to the probe by using a minimal depth and a higher frequency to provide the best resolution. To view deeper structures the operator increases the depth of the field of view and then manually tunes the transmit frequency to improve the image quality. In some systems, the ultrasound system may automatically adjust the transmit frequency based on the new depth. This automatic adjustment may "de-tune" selections made by the operator specific to the patient.

[0005] The operator may change (increase and decrease) the depth at various times throughout the exam. Manual tuning of the transmit frequency is time consuming and does not always result in optimal image quality as the operator may forget to adjust the frequency and/or select an incorrect frequency. For example, lack of information and increased noise in the far field result when depth is increased and the frequency is not adjusted properly. Also, poor resolution results when the depth is decreased and the frequency is not adjusted properly.

[0006] In some cases, a predetermined combination of scanning parameters, such as a depth, associated transmit frequency and beam-density (frame-rate) may be stored in an application preset that is selectable by the operator through a preset button or other selectable device. The application presets do not take into account differences in patients and anatomy, and thus the operator may still need to optimize scanning parameters after selecting the application preset. When the operator subsequently changes the depth or transmit frequency during the procedure, the scanning parameters may again need to be manually optimized.

[0007] Therefore, a need exists for a system that provides automatic adjustment of the scanning parameters to optimize scanning and that also preserves operator optimizations, if present.

BRIEF DESCRIPTION OF THE INVENTION

[0008] In one embodiment, an ultrasonic probe has transducer elements for transmitting and receiving ultrasound signals to form an ultrasound image. An optimization module receives a first scanning depth based on the ultrasound image and determines a first transmit pattern and receive filter settings based on the first scanning depth. The first transmit pattern and the receive filter settings are used to acquire the ultrasound image. Transmit and receive circuitry transmit and receive the ultrasound signals based on the first transmit pattern.

[0009] In another embodiment, a method for optimizing an ultrasound image comprises scanning with a first transmit pattern based on a first scanning depth to acquire an ultrasound image in a first scanning mode. A second scanning depth is received that is different with respect to the first scanning depth. A second transmit pattern is selected based on the second scanning depth, the first and second transmit patterns being different with respect to each other.

[0010] In yet another embodiment, a method for optimizing an ultrasound image comprises selecting a first transmit pattern based on a first scanning depth within an ultrasound image. The first transmit pattern further defines values for at least one of pulse sequence, shape of pulses, number of pulses, amplitude of pulses, and transmit frequency. A first beam-density is selected based on at least the first scanning depth. A second scanning depth is received that is different with respect to the first scanning depth. A second transmit pattern and a second beam-density are selected based on the second scanning depth wherein the second transmit pattern is different with respect to the first transmit pattern.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. **1** illustrates a block diagram of an ultrasound system formed in accordance with an embodiment of the present invention.

[0012] FIG. **2** illustrates a miniaturized ultrasound system formed in accordance with an embodiment of the present invention.

[0013] FIG. **3** illustrates an example of optimal scanning parameters that may be stored within a memory of an ultrasound system in accordance with an embodiment of the present invention.

[0014] FIG. **4** illustrates a first image that comprises ultrasound data associated with a first scanning depth in accordance with an embodiment of the present invention

[0015] FIG. **5** illustrates a second image that comprises ultrasound data associated with a second scanning depth in accordance with an embodiment of the present invention.

[0016] FIG. **6** illustrates a method for automatically optimizing scanning parameters for acquiring an ultrasound image in accordance with an embodiment of the present invention.

[0017] FIG. **7** illustrates an example of a series, family or set of optimal curves that represent optimal transmit patterns as a function of scanning depth and/or transmit frequency in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0018] The foregoing summary, as well as the following detailed description of certain embodiments of the present invention, will be better understood when read in conjunction with the appended drawings. To the extent that the figures illustrate diagrams of the functional blocks of various embodiments, the functional blocks are not necessarily indicative of the division between hardware circuitry. Thus, for example, one or more of the functional blocks (e.g., processors or memories) may be implemented in a single piece of hardware (e.g., a general purpose signal processor or random access memory, hard disk, or the like). Similarly, the programs may be stand alone programs, may be incorporated as subroutines in an operating system, may be functions in an installed software package, and the like. It should be understood that the various embodiments are not limited to the arrangements and instrumentality shown in the drawings.

[0019] FIG. **1** illustrates a block diagram of an ultrasound system **100**. The ultrasound system **100** includes a transmitter **102** that drives transducer elements **104** within a probe **106** to emit pulsed ultrasonic signals into a body. The transmitter **102** transmits the ultrasonic signals in a transmit pattern that is further discussed below. A variety of probe geometries may be used. The ultrasonic signals are back-scattered from structures in the body, like blood cells or muscular tissue, to produce echoes that return to the transducer elements **104**. The returning echoes are converted back to electrical energy by the transducer elements **104** which are received by a receiver **108**. The received signals are passed through a beamformer **110** that performs beamforming (combining the transducer element signals to perform steering and focusing of the beam) and outputs an RF signal. The receiver **108** and/or beamformer **110** may process the received signals with receive filter settings that are based at least on a defined depth. The RF signal then passes through an RF processor **112**. Alternatively, the RF processor **112** may include a complex demodulator (not shown) that demodulates the RF signal to form IQ data pairs representative of the echo signals. The RF or IQ signal data may then be routed directly to an RF/IQ buffer **114** for temporary storage.

[0020] A user input **120** may be used to control operation of the ultrasound system **100**, including, to control the input of patient data, scan parameters, change scanning parameters such as transmit pattern, transmit frequency, change a depth parameter, and the like, and may also include using voice commands provided via a microphone **230**. Other various embodiments such as a set of user controls may be configured for controlling the ultrasound system **100** and may be provided, for example, as part of a touch screen or panel, and as manual inputs, such as user operable switches, buttons, and the like. The set of user controls may be manually operable or voice operated.

[0021] The ultrasound system **100** also includes a processor **116** to process the acquired ultrasound information (i.e., RF signal data or IQ data pairs) and prepare frames of ultrasound information for display on display **118**. The display **118** has a known resolution that may be defined in terms of pixels or other known parameter. The processor **116** is adapted to perform one or more processing operations according to a plurality of selectable ultrasound modalities on the acquired ultrasound information. Acquired ultrasound information may be processed in real-time during a scanning session as the echo signals are received.

[0022] An optimization and adaptive control module **124** (hereafter optimization module **124**) may access optimal scanning parameters **126** stored within a memory **122** to automatically control the scanning parameters. The optimization module **124** and optimal scanning parameters **126** may be implemented in hardware or software, or a combination thereof. The optimization module **124** may automatically detect or receive a scanning depth as an input parameter. For example, when a probe **106** is first connected to the system **100** or when the operator selects a preset or a particular application protocol, the system **100** may set a depth parameter at a predetermined initial depth setting that is provided to the optimization module **124** as an input parameter. The operator may manually control the scanning depth by using the user input **120** to increase and decrease the scanning depth. Any operator change to the depth parameter is also provided to the optimization module **124**. The scanning depth may identify the penetration depth of a scanning image and/or a depth of a subset of the scanning image, such as the depth of a range gate or region of interest (ROI). The optimization module **124** may automatically optimize scanning parameters based on the depth, such as by accessing predefined tables, charts, databases, formulas, and/or other mapping functionality stored within the optimal scanning parameters **126**. The optimization may also change based on one or more of the type of probe **106** being used, an operational mode of the system **100** and/or a scanning protocol being used.

[0023] The optimization module **124** also provides adaptive control to reflect and thus preserve operator changes to scanning parameters such as the transmit frequency. For example, while the ultrasound system **100** may typically assume a constant acoustic velocity of 1540 m/s, in practice the ultrasound energy is influenced by the acoustical impedance of the patient, which may vary from patient to patient and from one anatomical structure to the next. Therefore, customizations based on operator input, such as to reflect specific patient characteristics and/or operator preference, may automatically be applied even when the depth is further changed.

[0024] It should be understood that the functionality discussed with respect to the system **100** is not limited to any ultrasound system type. For example, the system **100** may be housed within a cart-based system or may be implemented in a smaller, portable system as discussed in FIG. **2**.

[0025] FIG. **2** illustrates a miniaturized ultrasound system **10** having a probe **12** configured to acquire ultrasonic data. As used herein, "miniaturized" means that the ultrasound system is a handheld or hand-carried device or is configured to be carried in a person's hand, pocket, briefcase-sized case, or backpack. For example, the ultrasound system **100** may be a hand-carried device having a size of a typical laptop computer, for instance, having dimensions of approximately 2.5 inches in depth, approximately 14 inches in width, and approximately 12 inches in height. The ultrasound system **100** may weigh about ten pounds, and thus is easily portable by the operator. An integrated display **14** (e.g., an internal display) is also provided and is configured to display a medical image.

[0026] The ultrasonic data may be sent to external device **24** via a wired or wireless network **26** (or direct connection, for example, via a serial or parallel cable or USB port). In some embodiments, external device **24** may be a computer or a workstation having a display. Alternatively, external device **24** may be a separate external display or a printer capable of receiving image data from the hand carried ultrasound system **10** and of displaying or printing images that may have greater resolution than the integrated display **14**. The integrated display **14** and external device **24** may each have a different resolution that is known to the ultrasound system **10**.

[0027] A user interface **28** (that may also include integrated display **14**) is provided to receive commands from an operator, such as to change the scanning depth. Scanning parameters may be modified based on the resolution of the integrated display **14**, on a different external display **24**, or based on an operator defined resolution. Therefore, the acquired image data may be acquired in a higher resolution than that displayable on integrated display **14**.

[0028] As another example, the ultrasound system **10** may be a pocket-sized ultrasound system. By way of example, the pocket-sized ultrasound system may be approximately 2 inches wide, approximately 4 inches in length, and approximately 0.5 inches in depth and weigh less than 3 ounces. The pocket-sized ultrasound system may include a display, a user interface (i.e., keyboard) and an input/output (I/O) port for connection to the probe (all not shown). It should be noted that the various embodiments may be implemented in connection with a miniaturized ultrasound system having different dimensions, weights, and power consumption.

[0029] FIG. **3** illustrates an example of optimal scanning parameters **126** that may be stored within the memory **122** (shown in FIG. **1**). Optimal scanning parameters **126** may be determined for each of a plurality of different probes, such as a 3-5 MHz probe **300**, a 5-7 MHz probe **302** and a 1-3 MHz probe **304**. For each of the probes **300-304**, at least one set of optimal scanning parameters may be determined and multiple sets of optimal scanning parameters may be determined for different operational modes. It should be noted that not all of the probes **300-304** may be configured to operate in each of the modes, and that not all possible probes types and operational or scanning modes are illustrated in FIG. **3**. Generally, for each different probe, each mode may have a different set of scanning parameters, although overlap may exist.

[0030] For the 3-5 MHz probe **300**, three scanning modes or modes of operation are indicated as B-mode **306**, M-mode **308** and Color Flow Mode (CFM) **310**. For each mode **306-310**, an optimal transmit pattern, receive filters and beam-density are identified. For example, optimal transmit pattern **312**, receive filters settings **314** and beam-density **316** are identified for the 3-5 MHz probe **300** operating in the B-mode **306**. The optimal transmit pattern **312** may comprise one or more parameters such as pulse sequence, shape of pulses, number of pulses, amplitude of pulses, and transmit frequency. Other parameters may be defined within the optimal transmit pattern **312**. As discussed further below, the beam-density **316** may be further based on a display resolution or an operator defined resolution.

[0031] FIGS. **4** and **5** illustrate first and second images **150** and **160** that comprise ultrasound data having different scanning depths that may be acquired by the probe **106**. The first image **150** has a first depth **152** of approximately 9 cm while the second image **160** has a second depth **164** of approximately 12 cm. In this example, the scanning depth parameter of the first and second depth **152** and **164** refers to the penetration depth of the field of view (FOV) of the ultrasound image (e.g. first and second images **150** and **160**) that may be displayed on the display **118** of FIG. **1** and integrated display **14** of FIG. **2**. The values for the first and second depth **152** and **164** may be displayed proximate to the first and second images **150** and **160** for reference. Optionally, the values for the first and second depth **152** and **164** may be displayed in a different location, such as along an edge region **154** of the display **118**. Other scanning parameters, such as scanning mode (e.g. B-mode, CFM, M-mode, pulsed-wave (PW) Doppler mode, and the like) and transmit frequency, as well as other scanning parameters that are used to form the first image **150**, may also be displayed on the display **118**, such as within the edge region **154** or as an overlay over or proximate to the first image **150**.

[0032] In another embodiment, the depth may be determined relative to a range gate or region of interest (ROI) **166**, such as along a center **168** of the ROI **166** as illustrated on the first image **150**. For example, if Doppler is used, a range gate may be defined and if CFM mode is used the ROI **166** may be defined.

[0033] FIG. **6** illustrates a method for automatically optimizing scanning parameters for acquiring an ultrasound image. At **200**, an operator initiates an ultrasound scan using the system **100** or **10** of FIGS. **1** and **2**, respectively, and the probe **106** or **12**, respectively. For simplicity, the system **100** and components thereof will primarily be discussed below. The operator may choose the type of probe **106** based on exam properties or requirements or on the scanning mode to be used. At **202**, the operator may identify a scanning mode, such as by entering the data manually or by selecting a preset or predetermined protocol. As discussed previously, the scanning mode may be one of B-mode, CFM, M-mode, PW Doppler mode, or other imaging mode known in the art. The scanning mode is not limited to those discussed herein.

[0034] At **204**, the optimization module **124** identifies an initial scanning depth, such as by receiving an operator input that selects the initial scanning depth and/or by receiving a scanning depth parameter from the processor **116**. The optimization module **124** may also retrieve the initial scanning depth, such as from a predetermined location in the memory **122**. The scanning depth may be a penetration depth or a depth defined relative to the ROI **166**, such as at the center **168** as is illustrated in FIG. **4**. As discussed previously, the initial scanning depth may also be a preset value determined by a protocol, an application preset, a default position of the ROI **166**, and/or associated with the type of probe **106** being used.

[0035] Optimal scanning parameters are then determined to acquire the first image **150** at the initial depth. At **206**, the optimization module **124** may determine an optimal transmit pattern that defines one or more of pulse sequence, shape of pulses, number of pulses, amplitude of pulses, and transmit frequency as discussed previously. The optimization module **124** may also determine optimal receive filter settings (used by the receiver **108** and/or the beamformer **110**). Referring to FIG. **3**, if the probe **106** is the 3-5 MHz probe **300** acquiring data in B-mode **306**, the optimal transmit pattern **312** and receive filters settings **314** may be applied.

[0036] FIG. **7** illustrates an example of a series, family or set of optimal curves **240**, each of which represents an optimal transmit pattern as a function of scanning depth and/or transmit frequency. The set of optimal curves **240** may comprise a plurality of curves such as first optimal curve **242**, second optimal curve **244** above the first optimal curve **242** and third optimal curve **246** below the first optimal curve **242**. Although three optimal curves are shown, it should be understood that a set of optimal curves may comprise more or less than three optimal curves. The first optimal curve **242** may represent a standard or average echnogenity, the second optimal curve **244** may represent a relatively high echogenity with respect to the first optimal curve **242**, and the third optimal curve **246** may represent a relatively low echogenity with respect to the first optimal curve **242**. Each of the first through third optimal curves **242-246** represents a set of parameters that may be optimal for a different type of patient and/or anatomy. By way of example, the set of optimal curves **240** may be applicable for a probe **106** having a frequency range from 3-5 MHz, such as the probe **300** of FIG. **3**. Also, the set of optimal curves **240** may be applicable for a particular imaging mode, such as B-mode **306**, and the optimal transmit pattern **312** may be based on one of the first through third optimal curves **242-246**. Other probes having other frequency ranges may have their own set of optimal curves, and additional curves may exist for each imaging mode.

[0037] Returning to **206** of FIG. **6**, the optimization module **124** may identify the first optimal curve **242** which may be based on previous studies or representative of a large percentage of patient data. Optionally, the first optimal curve **242** may be the mean or average curve of the set of optimal curves **240**. In an example, first point **252** may be defined on the first optimal curve **242** based on the first depth **152** of approximately 9 cm of the first image **150** of FIG. **4**. Based on the first point **252**, a transmit frequency (one of the components of the optimal transmit pattern **312**) of 4 MHz may be selected.

[0038] At **208**, the optimization module **124** may identify an optimal beam-density **316** and/or or frame-rate. The beam-density **316** may be selected based on both the scanning depth (at **204**) and the resolution of one or more displays **118** interconnected with the system **100**. For example, the beam-density **316** may be selected based on the pixel resolution of the display **118** such that the beam or line density results in an image having a resolution that is approximate to or not much higher than the resolution of the display **118**. Optionally, the beam-density **316** may be determined by the operator defined resolution and/or by an external display or device, such as the external device **24** of FIG. **2**, in which case the beam-density **316** may be greater than can be displayed on the integrated display **14**. For example, it may be desirable to acquire data at a greater beam-density to save, display and/or print, simultaneous with the acquisition or later, at a resolution higher than the resolution of the integrated display **14**.

[0039] The optimal scanning parameters identified at **206** and **208** are used to acquire imaging data until the scanning depth is changed or the operator manually changes a scanning parameter, such as through the user input **120**. For example, the operator may optionally modify or change scanning parameters or parameters of the transmit pattern, such as the transmit frequency, select different receive filters that are applied by the receiver **108** and/or beamformer **110**, and/or change the beam-density or frame-rate to modify the first image **150**. The scanning depth change will be discussed first.

[0040] At **210**, if the system **100** detects that the operator has changed the scanning depth, the method continues to **212**. For example, the first depth **152** may be manually changed by the operator, such as by turning a knob or activating another device on the user input **120**. As discussed previously, the scanning depth change may be a change in penetration depth or a depth of the ROI **166** or sample gate. Turning to FIG. **5**, the second image **160** has a greater penetration depth with respect to the first image **150** of FIG. **4**. In this example, the first depth **152** has been increased to a second depth **164** of 12 cm to allow the operator to view anatomical structures located further from the probe **106**.

[0041] Returning to FIG. **6**, at **212** the optimization module **124** identifies an optimal transmit pattern **312** for the current scanning depth. In the example above, the current scanning depth is 12 cm. The optimization module **124** moves along the first optimal curve **242** (of FIG. **7**) from the first point **252** to a second point **254** that corresponds to 12 cm in depth. The transmit frequency may now be approximately 3 MHz. Other parameters within the optimal transmit pattern **312** may also change, as well as the receive filter settings **314**. In one embodiment, the optimization module **124** may access data within the optimal scanning parameters **126**, such as a chart, database, configuration file(s) and the like, to determine new parameters for one or more parameters within the optimal transmit pattern **312** based on the current scanning depth. In another embodiment, if the current scanning depth is reflecting a change in the depth of the center **168** of the ROI **166** (FIG. **4**), the optimization module **124** will also identify an optimal transmit pattern **312** by moving along the current optimal curve. The beam-density **316** may also be changed based on the current scanning depth

[0042] At **214**, if the optimization module **124** determines that the operator has changed a scanning parameter other than the scanning depth, such as the transmit frequency, the method continues to **216** where the optimization module **124** adaptively controls the optimal transmit pattern **312** based on the change made by the operator. If the transmit frequency is changed, the optimization module **124** moves to a different optimal curve within the set of optimal curves **240**. By way of example and not limitation, when the operator decreases the transmit frequency, the optimization module **124** selects a lower curve with respect to the current curve, performing adaptation to lower patient echogenity. When the operator increases the transmit frequency, the optimization module **124** selects a higher curve with respect to the current curve, performing adaptation to higher patient echogenity. For example, assuming a current setting at the first point **252**, the operator may change the transmit frequency from approximately 4 MHz to approximately 3 MHz without changing the depth. The optimization module **124** selects a third point **256** on the third optimal curve **246**. The optimal transmit pattern **312** is now based on the third point **256** and the third optimal curve **246**.

[0043] Once the operator has changed a scanning parameter, the system **100** will adaptively determine any further scanning changes based on the operator changes. At **218** and **220**, the optimization module **124** monitors to determine whether a change in scanning depth or a change in a scanning parameter, respectively, has been made by the operator. If a change in scanning depth is detected at **218**, at **222** the optimization module **124** may access the optimal scanning parameters **126** to identify an optimal transmit pattern **312**, receive filter settings **314** and beam-density **316** based on the current scanning depth. For example, assuming a starting point of the third point **256** located on the third optimal curve **246**, if the operator changes the depth from approximately 9.5 cm to approximately 6 cm the optimization module **124** moves along the third optimal curve **246** to fourth point **258**. Therefore, the previous modifications the operator made to the scanning parameters have been adaptively taken into consideration when adjusting the optimal transmit pattern **312**.

[0044] If a change to a scanning parameter is detected at **220**, the method continues to **224** where the optimization module **124** adaptively controls the optimal transmit pattern **312** based on the scanning parameter change. For example, assuming a starting point of the third point **256** located on the third optimal curve **246**, if the operator changes the transmit frequency from approximately 3 MHz to approximately 5 MHz, the optimization module **124** may select a fifth point **260** along the second optimal curve **244**. The optimization module **124** identifies an optimal transmit pattern **312** based on the fifth point **260**, as well as optimal receive filter settings **314** and beam-density **316**. Therefore, changes the operator has made to the scanning parameters are adaptively reflected in the optimal transmit pattern **312**, and the optimal transmit pattern **312** is optimized based on the operator changes that were made to reflect the particular patient's anatomical composition, structure being imaged, operator preference, and the like.

[0045] A technical effect of at least one embodiment is automatically optimizing the transmit pattern during an ultrasonic examination based on changes to a scanning depth parameter. The transmit pattern comprises one or more of pulse sequence, shape of pulses, number of pulses, amplitude of pulses, and transmit frequency. The scanning depth may be a penetration depth or may be defined, for example, by an ROI or range gate. An optimal set of scanning parameters is associated with a probe and each probe may have more than one optimal set of scanning parameters that are each optimized for a particular imaging mode. When the operator changes the scanning depth during a scan, the system automatically optimizes the scanning parameters such as the transmit pattern, receive filter settings and beam-density. If the operator changes a scanning parameter such as the transmit frequency, the system adaptively applies the operator changes to determine the optimal scanning parameters.

[0046] It is to be understood that the above description is intended to be illustrative, and not restrictive. For example, the above-described embodiments (and/or aspects thereof) may be used in combination with each other. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from its scope. While the dimensions and types of materials described herein are intended to define the parameters of the invention, they are by no means limiting and are exemplary embodiments. Many other embodiments will be apparent to those of skill in the art upon reviewing the above description. The scope of the invention should, therefore, be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled. In the appended claims, the terms "including" and "in which" are used as the plain-English equivalents of the respective terms "comprising" and "wherein." Moreover, in the following claims, the terms "first," "second," and "third," etc. are used merely as labels, and are not intended to impose numerical requirements on their objects. Further, the limitations of the following claims are not written in means—plus-function format and are not intended to be interpreted based on 35 U.S.C. § 112, sixth paragraph, unless and until such claim limitations expressly use the phrase "means for" followed by a statement of function void of further structure.

What is claimed is:

1. An ultrasound system, comprising:

an ultrasonic probe having transducer elements for transmitting and receiving ultrasound signals to form an ultrasound image;

an optimization module for receiving a first scanning depth based on the ultrasound image, the optimization module determining a first transmit pattern and receive filter settings based on the first scanning depth, the first transmit pattern and the receive filter settings being used to acquire the ultrasound image; and

transmit and receive circuitry for transmitting and receiving the ultrasound signals based on the first transmit pattern.

2. The system of claim **1**, wherein the transmit pattern further comprises at least one of pulse sequence, shape of pulses, number of pulses, amplitude of pulses, and transmit frequency.

3. The system of claim **1**, wherein the optimization module further selects the first transmit pattern according to one curve within a set of optimal curves representing optimal transmit patterns as a function of scanning depth.

4. The system of claim **1**, further comprising a user input for selecting a second scanning depth, the optimization module determining a second transmit pattern based on the second scanning depth, the second transmit pattern being different than the first transmit pattern, and the transmit and receive circuitry transmitting and receiving ultrasound signals based on the second transmit pattern.

5. The system of claim **1**, further comprising a user input for changing at least one of a transmit pattern and a transmit frequency, the optimization module identifying a second transmit pattern based on a curve representing an optimal transmit pattern as a function of the first scanning depth.

6. The system of claim **1**, further comprising a display having a display resolution, the optimization module further determining a beam-density based at least on the display resolution, the transmit and receive circuitry transmitting and receiving the ultrasound signals based at least on the beam-density.

7. The system of claim **1**, wherein the ultrasound system is one of cart-based, portable, hand-held, hand carried and pocket sized.

8. A method for optimizing an ultrasound image, comprising:

scanning with a first transmit pattern based on a first scanning depth to acquire an ultrasound image, the ultrasound image being acquired in a first scanning mode;

receiving a second scanning depth that is different with respect to the first scanning depth; and

selecting a second transmit pattern based on the second scanning depth, the second transmit pattern being different with respect to the first transmit pattern.

9. The method of claim **8**, wherein the first and second transmit patterns further comprise at least one of pulse sequence, shape of pulses, number of pulses, amplitude of pulses, and transmit frequency.

10. The method of claim **8**, wherein the scanning further comprises defining first and second beam-densities based at least on the first and second scanning depths, respectively.

11. The method of claim **8**, wherein the first and second transmit patterns comprise a transmit frequency having first and second transmit frequency values, respectively.

12. The method of claim **8**, wherein the first and second transmit patterns comprise a transmit frequency having first and second transmit frequency values, respectively, the method further comprising:

receiving a third frequency value that is different with respect to the second frequency value; and

selecting a third transmit pattern based on the second scanning depth and the third frequency value.

13. The method of claim **8**, further comprising:

detecting a desired resolution associated with at least one of an integrated display, an external display, and an operator defined resolution; and

adjusting a beam-density based on the desired resolution.

14. The method of claim **8**, further comprising:

detecting a display resolution of a display being used to display the ultrasound image; and

selecting a beam-density of transmitted ultrasound beams based on the display resolution and the second scanning depth.

15. The method of claim **8**, further comprising:

selecting a second scanning mode that is different with respect to the first scanning mode; and

selecting a third transmit pattern based at least on the second scanning mode.

16. The method of claim **8**, wherein the first and second scanning depths are based on a region of interest located within the ultrasound image.

17. A method for optimizing an ultrasound image, comprising:

selecting a first transmit pattern based on a first scanning depth within an ultrasound image, the first transmit pattern further defining values for at least one of pulse sequence, shape of pulses, number of pulses, amplitude of pulses, and transmit frequency;

selecting a first beam-density based on at least the first scanning depth;

receiving a second scanning depth that is different with respect to the first scanning depth; and

selecting a second transmit pattern and a second beam-density based on the second scanning depth, the second transmit pattern being different with respect to the first transmit pattern.

18. The method of claim **17**, further comprising:

receiving a second transmit frequency value; and

selecting a third transmit pattern based on the second transmit frequency value.

19. The method of claim **17**, wherein the first and second transmit patterns are based on a set of optimal curves, the set of optimal curves representing optimal transmit patterns based on at least one of scanning depth and transmit frequency.

20. The method of claim **17**, wherein the first and second transmit patterns are based on at least one set of optimal curves, the at least one set of optimal curves being associated with at least one of a probe type and a scanning mode associated with the ultrasound image.

* * * * *

专利名称(译)	用于超声成像的扫描参数的自动优化的方法和设备

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摘要(译)

超声探头具有用于发送和接收超声信号以形成超声图像的换能器元件。优化模块基于超声图像接收第一扫描深度，并基于第一扫描深度确定第一发送模式和接收滤波器设置。第一发射模式和接收滤波器设置用于获取超声图像。发送和接收电路基于第一发送模式发送和接收超声信号