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(54) **SYSTEMS AND METHODS FOR ACQUIRING RAW ULTRASOUND DATA FROM AN ULTRASOUND MACHINE USING A WIRELESSLY CONNECTED DEVICE**

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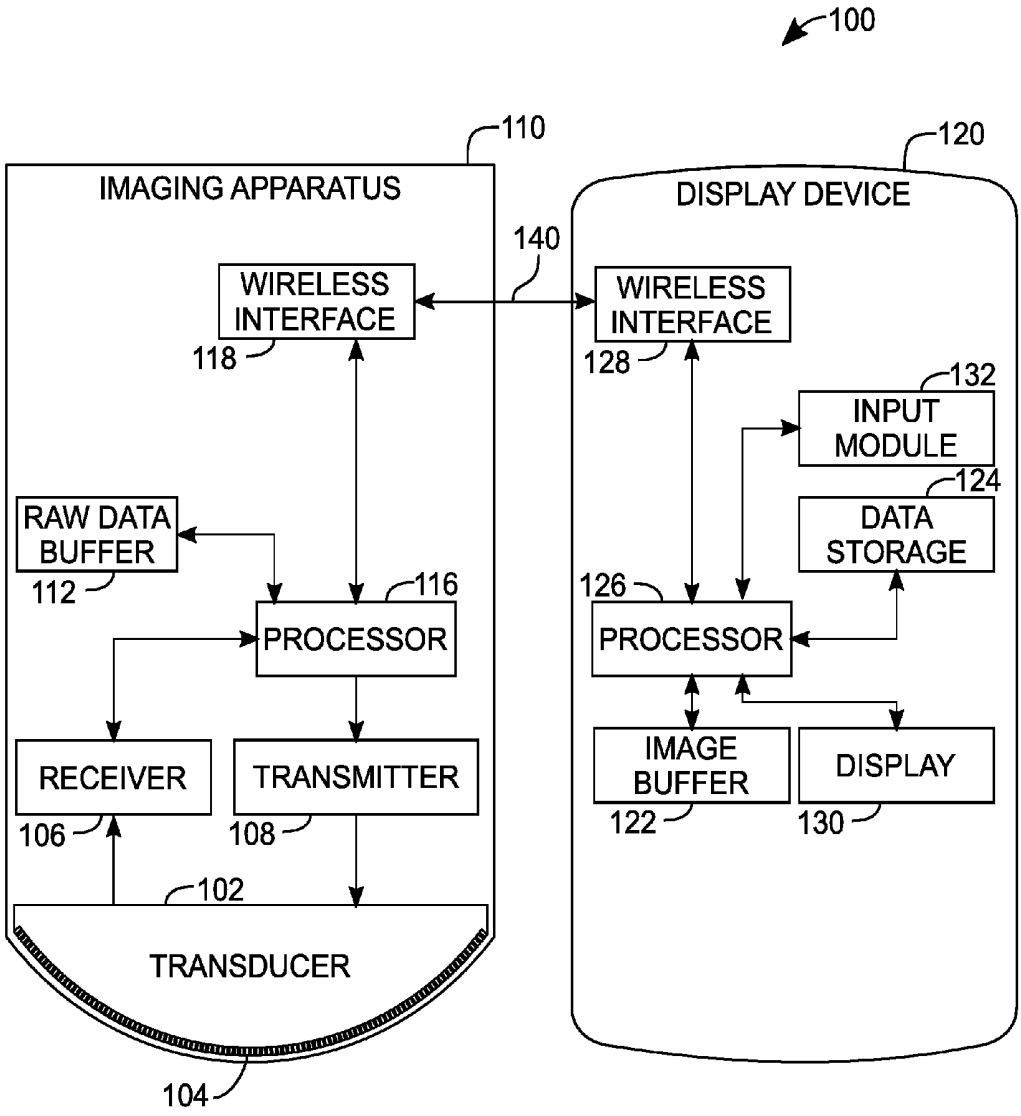
(57) **ABSTRACT**

The present embodiments relate generally to systems and methods for acquiring raw ultrasound data from an ultrasound machine using a wirelessly connected device. The systems can be configured to display ultrasound images on a display device and receive input to select the ultrasound images for which to retrieve corresponding raw ultrasound data from the ultrasound machine. A raw data buffer provided at the ultrasound machine may be capable of storing a first time duration of raw ultrasound data. An image display buffer provided at the wireless device may store: processed ultrasound image data corresponding to the raw ultrasound data stored in the raw data buffer; and previously-received processed ultrasound image data that has no corresponding raw ultrasound data stored in the raw data buffer.



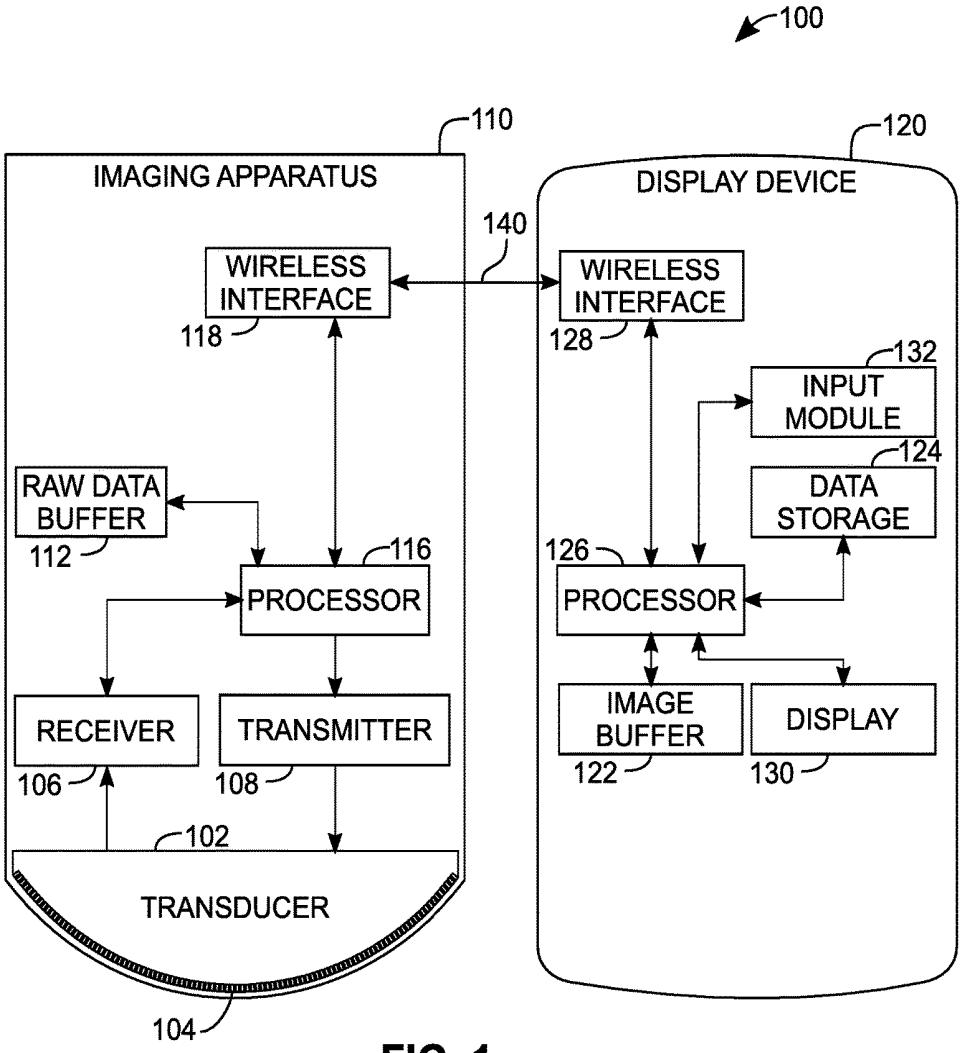

100
110
IMAGING APPARATUS
120
DISPLAY DEVICE
140
WIRELESS INTERFACE
118
WIRELESS INTERFACE
128
132
INPUT MODULE
124
DATA STORAGE
RAW DATA BUFFER
112
116
PROCESSOR
126
PROCESSOR
RECEIVER
106
TRANSMITTER
108
IMAGE BUFFER
122
DISPLAY
130
102
TRANSDUCER
104

FIG. 1

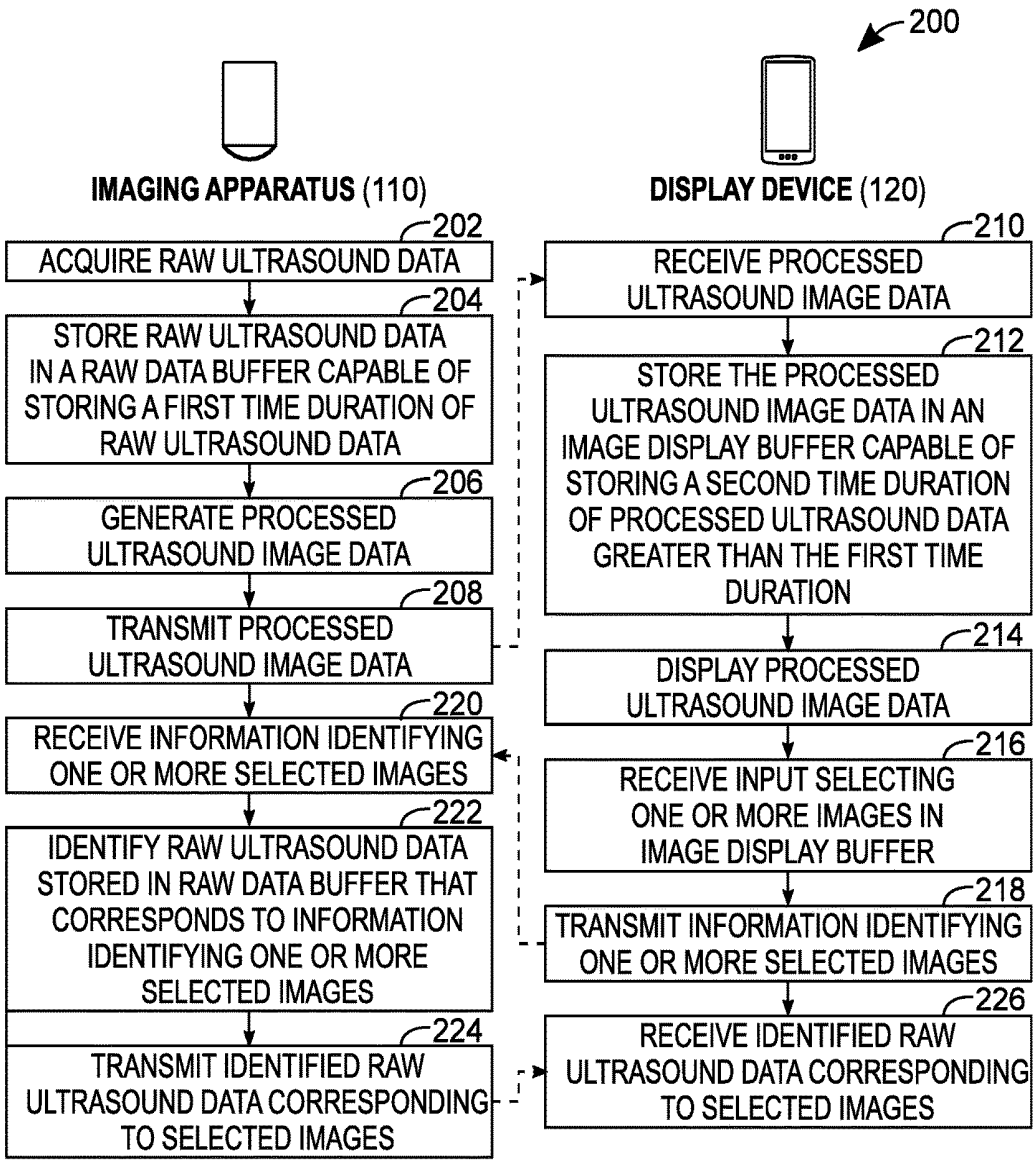

200
IMAGING APPARATUS (110)
DISPLAY DEVICE (120)
202
ACQUIRE RAW ULTRASOUND DATA
204
STORE RAW ULTRASOUND DATA IN A RAW DATA BUFFER CAPABLE OF STORING A FIRST TIME DURATION OF RAW ULTRASOUND DATA
206
GENERATE PROCESSED ULTRASOUND IMAGE DATA
208
TRANSMIT PROCESSED ULTRASOUND IMAGE DATA
220
RECEIVE INFORMATION IDENTIFYING ONE OR MORE SELECTED IMAGES
222
IDENTIFY RAW ULTRASOUND DATA STORED IN RAW DATA BUFFER THAT CORRESPONDS TO INFORMATION IDENTIFYING ONE OR MORE SELECTED IMAGES
224
TRANSMIT IDENTIFIED RAW ULTRASOUND DATA CORRESPONDING TO SELECTED IMAGES
210
RECEIVE PROCESSED ULTRASOUND IMAGE DATA
212
STORE THE PROCESSED ULTRASOUND IMAGE DATA IN AN IMAGE DISPLAY BUFFER CAPABLE OF STORING A SECOND TIME DURATION OF PROCESSED ULTRASOUND DATA GREATER THAN THE FIRST TIME DURATION
214
DISPLAY PROCESSED ULTRASOUND IMAGE DATA
216
RECEIVE INPUT SELECTING ONE OR MORE IMAGES IN IMAGE DISPLAY BUFFER
218
TRANSMIT INFORMATION IDENTIFYING ONE OR MORE SELECTED IMAGES
226
RECEIVE IDENTIFIED RAW ULTRASOUND DATA CORRESPONDING TO SELECTED IMAGES

FIG. 2

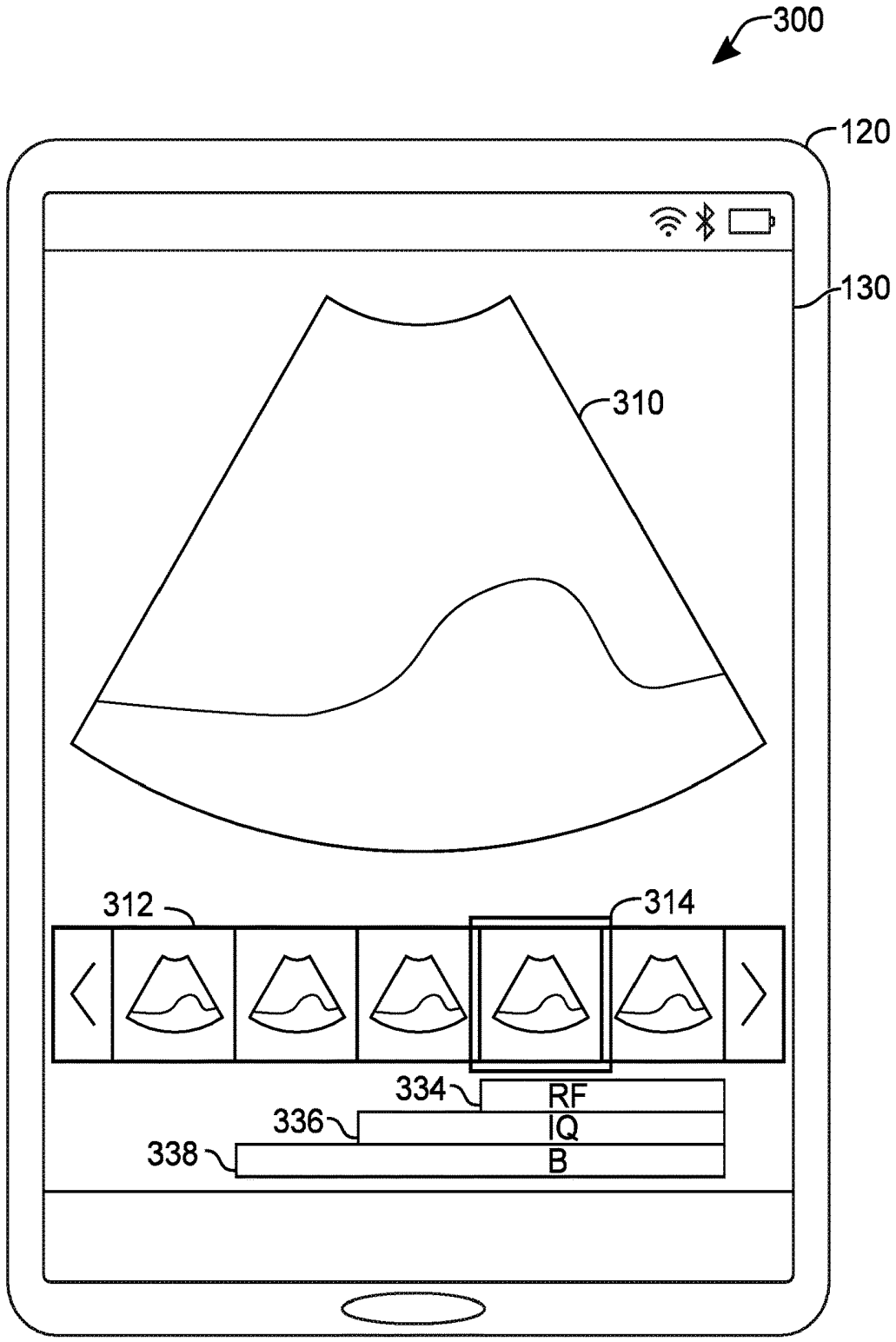



FIG. 3

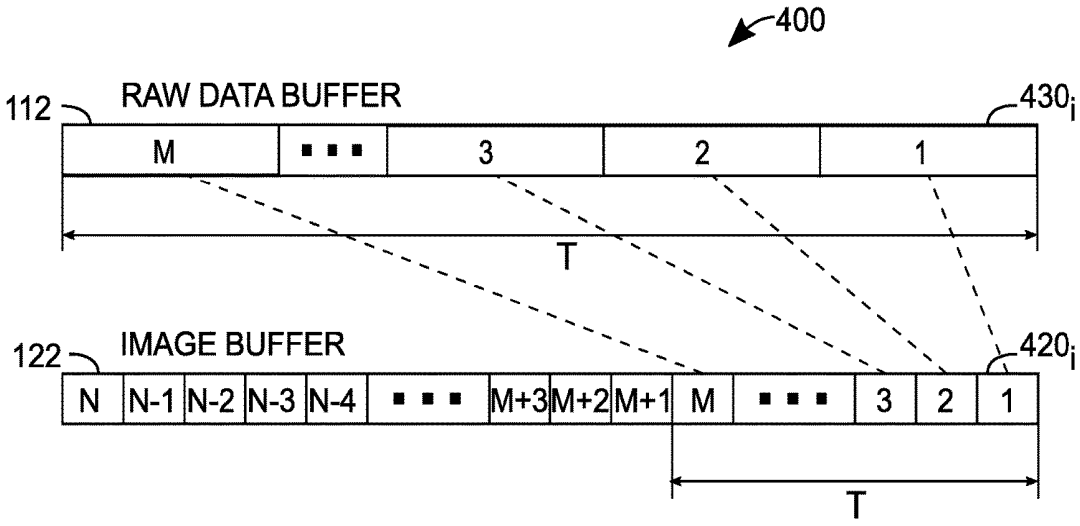

400
112
RAW DATA BUFFER
430i
M
3
2
1
T
122
IMAGE BUFFER
420i
N
N-1
N-2
N-3
N-4
M+3
M+2
M+1
M
3
2
1
T

FIG. 4

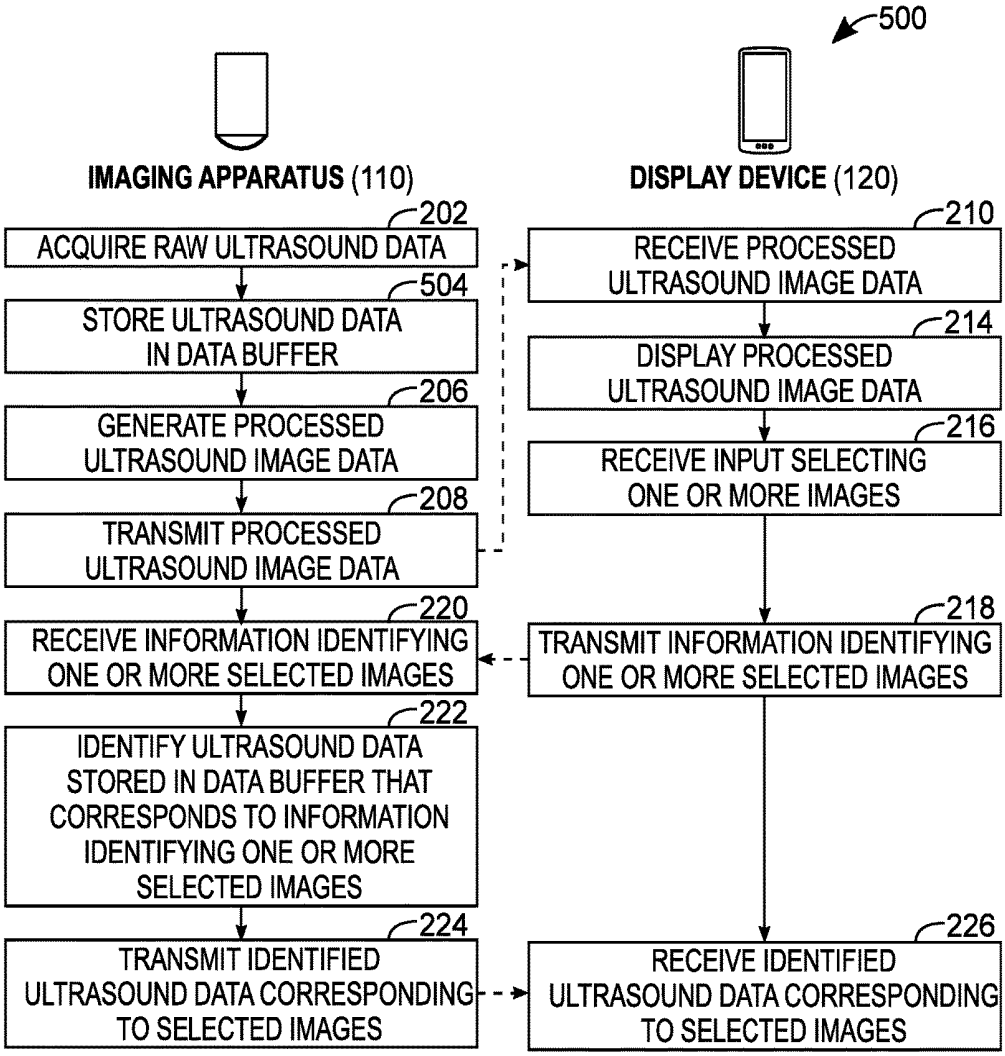

500
IMAGING APPARATUS (110)
DISPLAY DEVICE (120)
202
ACQUIRE RAW ULTRASOUND DATA
504
STORE ULTRASOUND DATA IN DATA BUFFER
206
GENERATE PROCESSED ULTRASOUND IMAGE DATA
208
TRANSMIT PROCESSED ULTRASOUND IMAGE DATA
220
RECEIVE INFORMATION IDENTIFYING ONE OR MORE SELECTED IMAGES
222
IDENTIFY ULTRASOUND DATA STORED IN DATA BUFFER THAT CORRESPONDS TO INFORMATION IDENTIFYING ONE OR MORE SELECTED IMAGES
224
TRANSMIT IDENTIFIED ULTRASOUND DATA CORRESPONDING TO SELECTED IMAGES
210
RECEIVE PROCESSED ULTRASOUND IMAGE DATA
214
DISPLAY PROCESSED ULTRASOUND IMAGE DATA
216
RECEIVE INPUT SELECTING ONE OR MORE IMAGES
218
TRANSMIT INFORMATION IDENTIFYING ONE OR MORE SELECTED IMAGES
226
RECEIVE IDENTIFIED ULTRASOUND DATA CORRESPONDING TO SELECTED IMAGES

FIG. 5

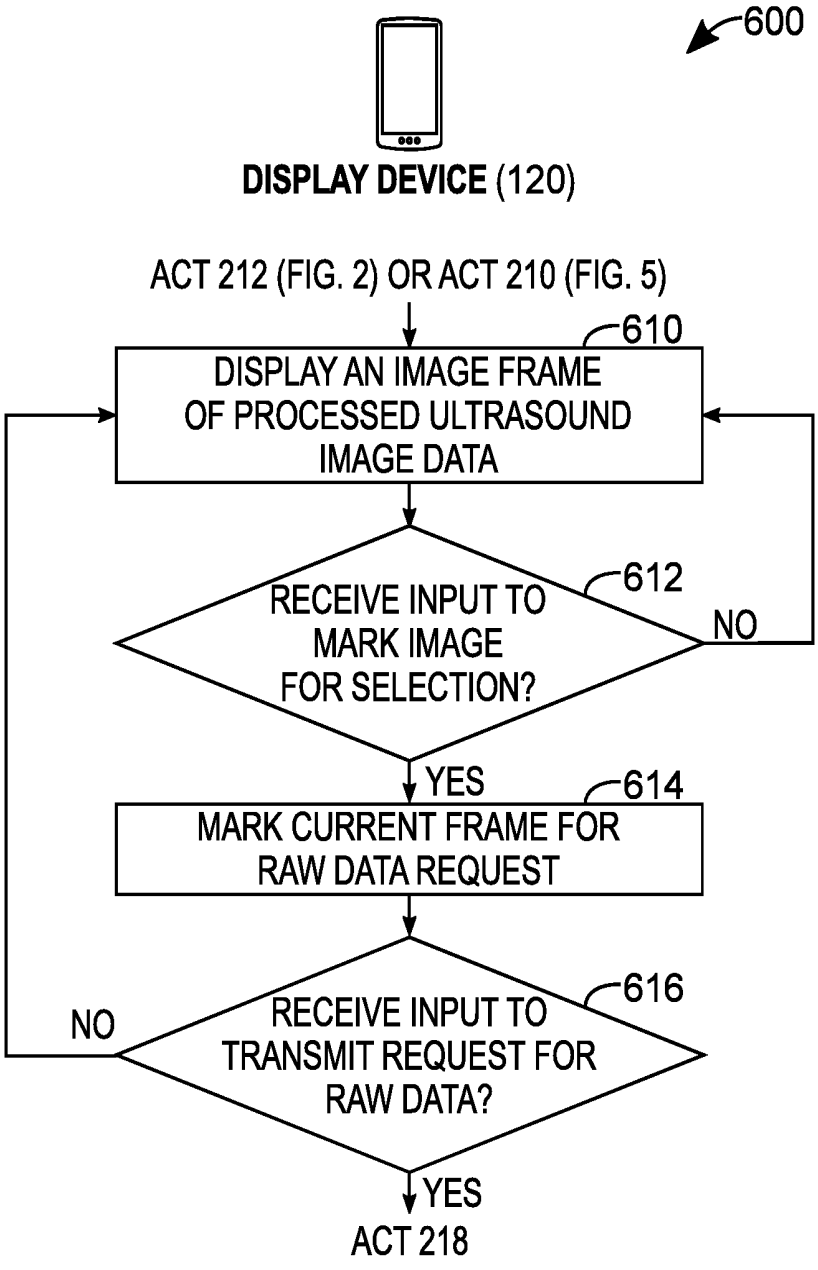

600
DISPLAY DEVICE (120)
ACT 212 (FIG. 2) OR ACT 210 (FIG. 5)
610
DISPLAY AN IMAGE FRAME OF PROCESSED ULTRASOUND IMAGE DATA
612
RECEIVE INPUT TO MARK IMAGE FOR SELECTION?
NO
YES
614
MARK CURRENT FRAME FOR RAW DATA REQUEST
616
RECEIVE INPUT TO TRANSMIT REQUEST FOR RAW DATA?
NO
YES
ACT 218

FIG. 6

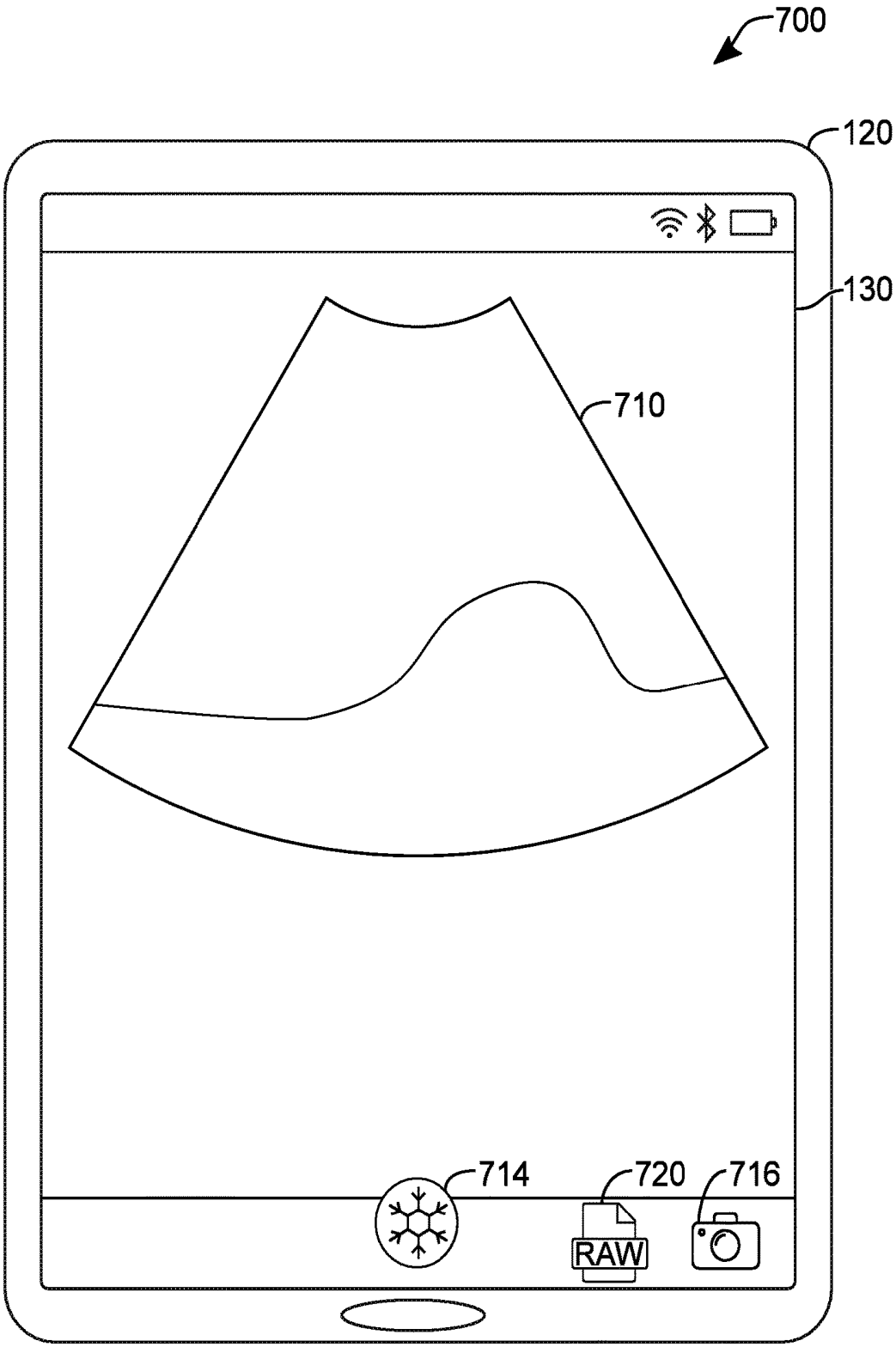



FIG. 7

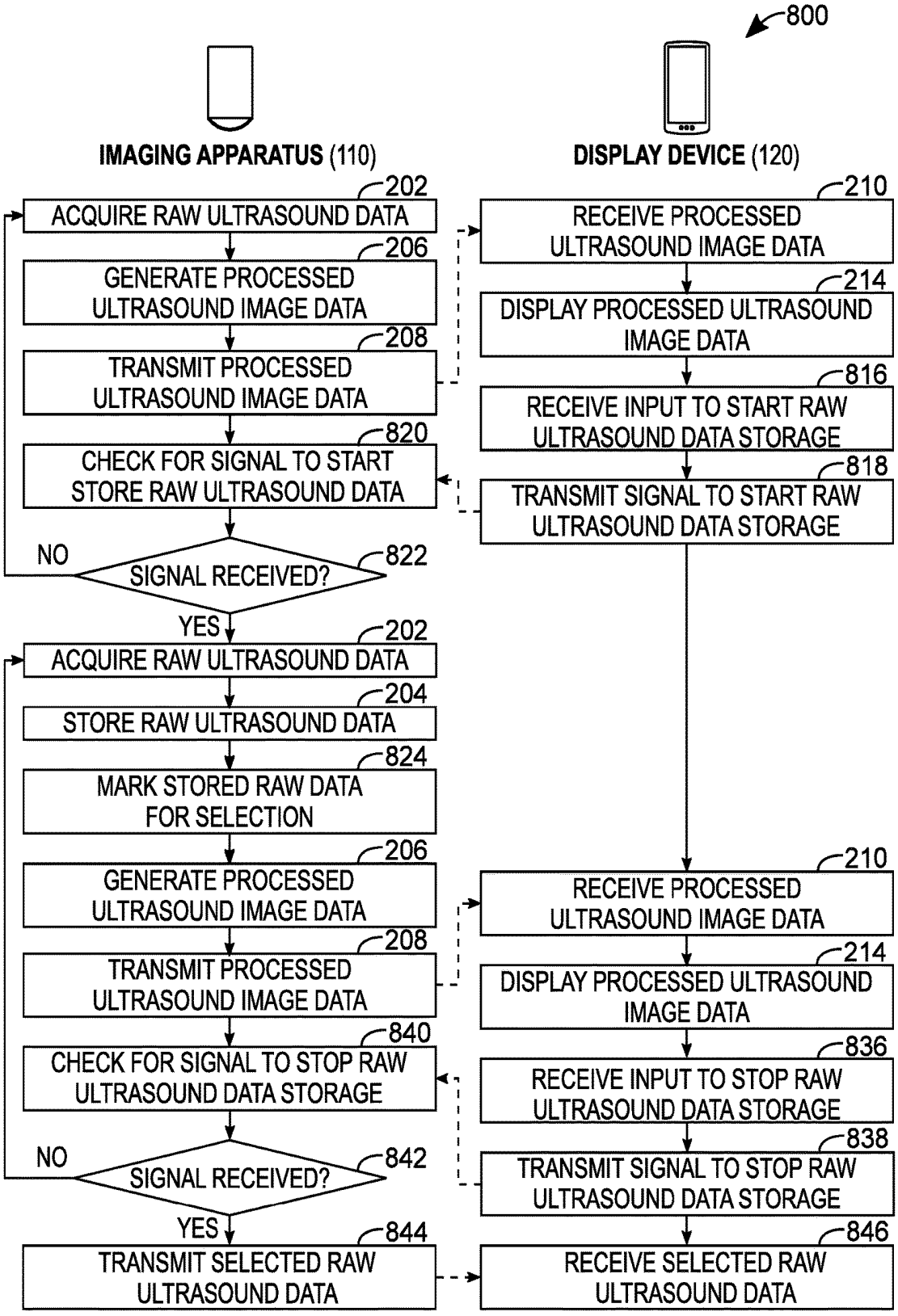

800
IMAGING APPARATUS (110)
DISPLAY DEVICE (120)
202
ACQUIRE RAW ULTRASOUND DATA
206
GENERATE PROCESSED ULTRASOUND IMAGE DATA
208
TRANSMIT PROCESSED ULTRASOUND IMAGE DATA
820
CHECK FOR SIGNAL TO START STORE RAW ULTRASOUND DATA
NO
SIGNAL RECEIVED?
822
YES
202
ACQUIRE RAW ULTRASOUND DATA
204
STORE RAW ULTRASOUND DATA
824
MARK STORED RAW DATA FOR SELECTION
206
GENERATE PROCESSED ULTRASOUND IMAGE DATA
208
TRANSMIT PROCESSED ULTRASOUND IMAGE DATA
840
CHECK FOR SIGNAL TO STOP RAW ULTRASOUND DATA STORAGE
NO
SIGNAL RECEIVED?
842
YES
844
TRANSMIT SELECTED RAW ULTRASOUND DATA
210
RECEIVE PROCESSED ULTRASOUND IMAGE DATA
214
DISPLAY PROCESSED ULTRASOUND IMAGE DATA
816
RECEIVE INPUT TO START RAW ULTRASOUND DATA STORAGE
818
TRANSMIT SIGNAL TO START RAW ULTRASOUND DATA STORAGE
210
RECEIVE PROCESSED ULTRASOUND IMAGE DATA
214
DISPLAY PROCESSED ULTRASOUND IMAGE DATA
836
RECEIVE INPUT TO STOP RAW ULTRASOUND DATA STORAGE
838
TRANSMIT SIGNAL TO STOP RAW ULTRASOUND DATA STORAGE
846
RECEIVE SELECTED RAW ULTRASOUND DATA

FIG. 8

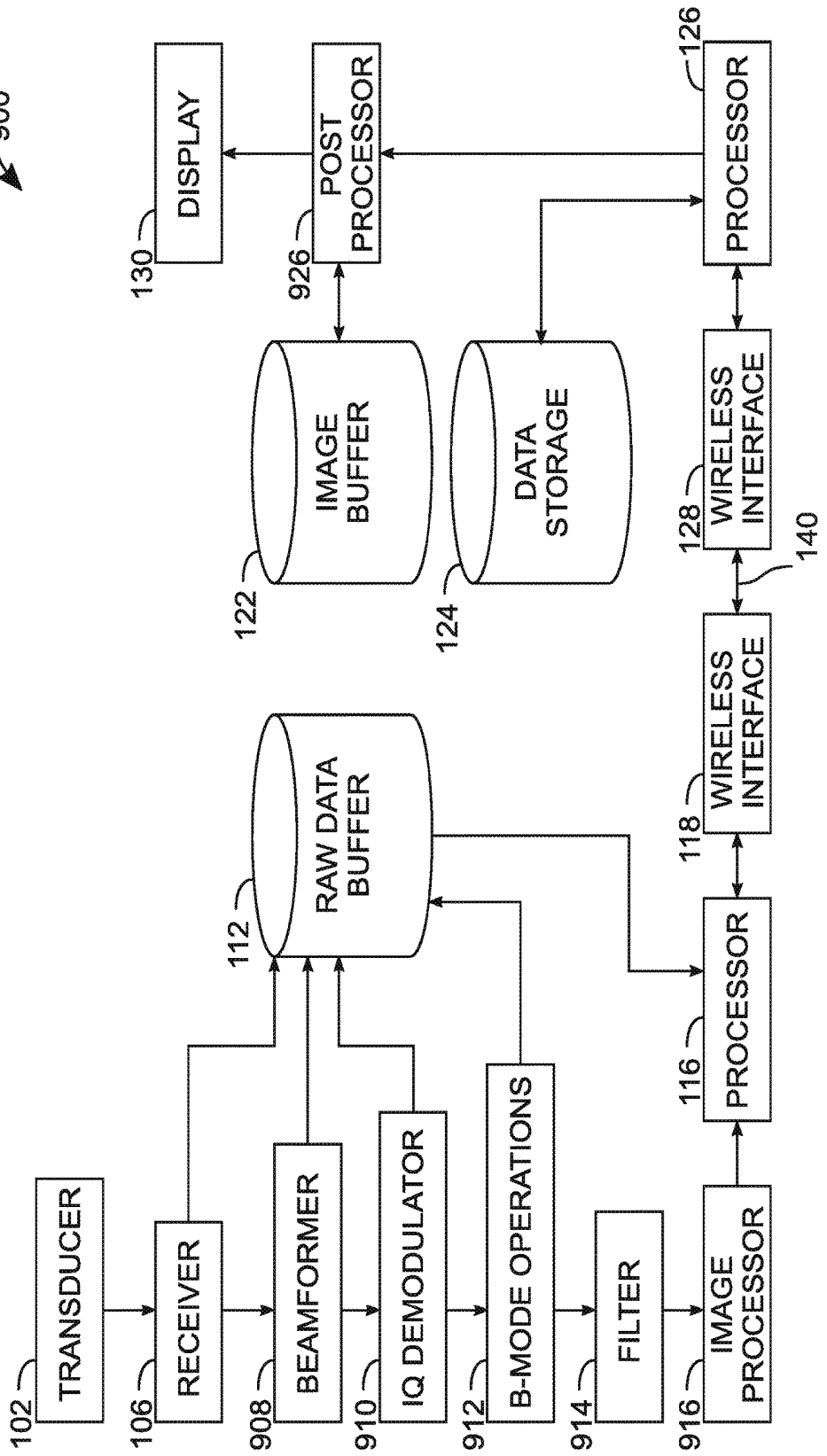

900
DISPLAY
130
POST PROCESSOR
926
PROCESSOR
126
IMAGE BUFFER
122
DATA STORAGE
124
WIRELESS INTERFACE
128
140
WIRELESS INTERFACE
118
RAW DATA BUFFER
112
PROCESSOR
116
TRANSDUCER
102
RECEIVER
106
BEAMFORMER
908
IQ DEMODULATOR
910
B-MODE OPERATIONS
912
FILTER
914
IMAGE PROCESSOR
916

FIG. 9

# SYSTEMS AND METHODS FOR ACQUIRING RAW ULTRASOUND DATA FROM AN ULTRASOUND MACHINE USING A WIRELESSLY CONNECTED DEVICE

## FIELD

**[0001]** This invention generally relates to ultrasound imaging systems, and in particular, systems and methods for acquiring raw ultrasound data from an ultrasound machine using a wirelessly connected device.

## BACKGROUND

**[0002]** Ultrasound imaging systems are a powerful tool for performing real-time, non-invasive imaging procedures in a wide range of medical applications. An ultrasound machine typically includes a transducer which sends out ultrasound signals into a target object. Ultrasound waves are reflected back from the target object and are received by the transducer. The received data is then subject to a number of processing steps to generate an ultrasound image of the target object.

**[0003]** As the raw received data is processed, a portion of the information contained in the raw data is lost as the size is reduced. Having access to this raw data may be useful for a number of reasons, including performing advanced analyses and research. Some ultrasound systems have specialized hardware to allow access to the raw data.

**[0004]** Some newer ultrasound machines include a wirelessly connected transducer that provides advantages over traditional corded ultrasound machines, including improved portability and ergonomics. Current wireless communication protocols such as Wi-Fi™ may not have the bandwidth required to stream both the images and raw data in real-time.

**[0005]** There is thus a need for improved ultrasound systems and methods that enable raw ultrasound data to be stored and transmitted from a wireless probe. The embodiments discussed herein may address and/or ameliorate at least some of the aforementioned drawbacks identified above. The foregoing examples of the related art and limitations related thereto are intended to be illustrative and not exclusive. Other limitations of the related art will become apparent to those of skill in the art upon a reading of the specification and a study of the drawings herein.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0006]** Non-limiting examples of various embodiments of the present disclosure will next be described in relation to the drawings, in which:

**[0007]** FIG. **1** is a functional block diagram of an ultrasound system, in accordance with at least one embodiment of the present invention;

**[0008]** FIG. **2** is a flowchart diagram of a method for acquiring raw data from an ultrasound machine using a wirelessly connected device, in accordance with at least one embodiment of the present invention;

**[0009]** FIG. **3** is a view of a graphical user interface for selecting ultrasound image frames for which to retrieve corresponding raw ultrasound data, in accordance with at least one embodiment of the present invention;

**[0010]** FIG. **4** is a schematic diagram of the image buffer and raw data buffer of FIG. **1**, in accordance with at least one embodiment of the present invention;

**[0011]** FIG. **5** is a flowchart diagram of a method for acquiring raw data from an ultrasound machine using a wirelessly connected device, in accordance with at least another embodiment of the present invention;

**[0012]** FIG. **6** shows a flowchart diagram of certain acts for selecting and retrieving raw ultrasound data, in accordance with at least one embodiment of the present invention;

**[0013]** FIG. **7** shows a view of a graphical user interface for retrieving raw ultrasound data, in accordance with at least one embodiment of the present invention;

**[0014]** FIG. **8** is a flowchart diagram of a method for acquiring raw data from an ultrasound machine using a wirelessly connected device, in accordance with at least another embodiment of the present invention; and

**[0015]** FIG. **9** is a data flow diagram of a method for selecting and retrieving raw ultrasound data from an ultrasound machine using a wirelessly connected device, in accordance with at least one embodiment of the present invention.

## DETAILED DESCRIPTION

**[0016]** In a first broad aspect of the present disclosure, there is provided a method for acquiring raw ultrasound data from an ultrasound machine using a wirelessly connected device, the method involving, at the wirelessly connected device: receiving processed ultrasound image data from the ultrasound machine, wherein the received processed ultrasound image data corresponds to raw ultrasound data stored in a raw data buffer at the ultrasound machine, wherein the raw data buffer is capable of storing a first time duration of raw ultrasound data, and the received processed ultrasound image data requires less storage capacity than the corresponding raw ultrasound data stored in the raw data buffer; storing the processed ultrasound image data in an image display buffer, the image display buffer being capable of storing a second time duration of processed ultrasound image data longer than the first time duration, and wherein the image display buffer simultaneously stores: (i) the received processed ultrasound image data corresponding to the raw ultrasound data stored in the raw data buffer, and (ii) previously-received processed ultrasound image data that has no corresponding raw ultrasound data stored in the raw data buffer; receiving input selecting one or more images of the received processed ultrasound image data stored in the image display buffer; transmitting information identifying the selected one or more images to the ultrasound machine, wherein the ultrasound machine identifies the raw ultrasound data, stored in the raw data buffer, that corresponds to the selected one or more images, for return to the wirelessly connected device; and receiving the identified raw ultrasound data corresponding to the selected one or more images.

**[0017]** In some embodiments, both (i) the received processed ultrasound image data corresponding to the raw ultrasound data stored in the raw data buffer at the ultrasound machine and (ii) the previously-received processed ultrasound image data stored in the image display buffer are viewable in a user interface of the wirelessly connected device that navigates images stored in the image display buffer.

**[0018]** In some embodiments, prior to receiving input selecting the one or more images, the user interface is configured to display an image of the received processed ultrasound image data, and the user interface indicates that

corresponding raw ultrasound data is available to be retrieved from the ultrasound machine.

**[0019]** In some embodiments, prior to receiving input selecting the one or more images, the user interface is configured to display an image from the previously-received processed ultrasound image data, and the user interface does not indicate that corresponding raw ultrasound data is available to be retrieved from the ultrasound machine.

**[0020]** In some embodiments, the method further involves storing the received raw ultrasound data, corresponding to the selected one or more images, in a storage location different from the image display buffer.

**[0021]** In some embodiments, prior to receiving the processed ultrasound image data, the method further involves: receiving input indicating a raw ultrasound data collection mode of the ultrasound machine is to be activated; and directing the ultrasound machine to activate the raw ultrasound data collection mode.

**[0022]** In some embodiment, prior to receiving the input indicating the raw ultrasound data collection mode is to be activated, the method further involves: operating in an imaging mode where the previously-received processed ultrasound image data is received, and no corresponding raw ultrasound data is stored in the raw data buffer at the ultrasound machine.

**[0023]** In some embodiments, prior to receiving the input indicating the raw ultrasound data collection mode of the ultrasound machine is to be activated, the method further involves: receiving an ultrasound image feed including the previously-received processed ultrasound image data; and displaying the ultrasound image feed; and wherein during receipt of the input indicating the raw ultrasound data collection mode at the ultrasound machine is to be activated, the method further involves continuing to receive and display the ultrasound image feed, the ultrasound image feed including the received processed ultrasound image data.

**[0024]** In some embodiments, the ultrasound image feed is continued to be received and displayed when the raw ultrasound data collection mode is activated without substantial delay in displaying successive frames of the ultrasound image feed.

**[0025]** In some embodiments, after the received processed ultrasound image data is stored in the image display buffer, the method further involves: receiving input indicating the raw ultrasound data collection mode of the ultrasound machine is to be deactivated; and directing the ultrasound machine to deactivate the raw ultrasound data collection mode.

**[0026]** In some embodiments, the input indicating the raw ultrasound data collection mode of the ultrasound machine is to be activated involves pressing of a button on a user interface provided on one of the ultrasound machine and the wirelessly connected device, and the received input indicating the raw ultrasound data collection mode of the ultrasound machine is to be deactivated involves a release of the button.

**[0027]** In some embodiments, prior to receiving the input selecting one or more images from the received processed ultrasound image data stored in the image display buffer, the method further involves: receiving input to stop ultrasound data acquisition at the ultrasound machine; and directing the ultrasound machine to stop ultrasound data acquisition.

**[0028]** In another broad aspect of the present disclosure, there is provided a method for transmitting raw ultrasound data from an ultrasound machine to a wirelessly connected device, the method including, at the ultrasound machine: acquiring raw ultrasound data; storing the acquired raw ultrasound data in a raw data buffer, wherein the raw data buffer is capable of storing a first time duration of raw ultrasound data; generating processed ultrasound image data from the raw ultrasound data, the processed ultrasound image data requiring less storage capacity than the acquired raw ultrasound data; transmitting the processed ultrasound image data to the wirelessly connected device, wherein the transmitted processed ultrasound image data is stored at the wirelessly connected device in an image display buffer, the image display buffer being capable of storing a second time duration of processed ultrasound image data longer than the first time duration, and wherein the image display buffer simultaneously stores: (i) the transmitted processed ultrasound image data corresponding to the raw ultrasound data stored in the raw data buffer, and (ii) previously-transmitted processed ultrasound image data that has no corresponding raw ultrasound data stored in the raw data buffer; receiving, from the wirelessly connected device, information identifying one or more images selected from the transmitted processed ultrasound image data; identifying the raw ultrasound data, stored in the raw data buffer, corresponding to the one or more images; and transmitting, to the wirelessly connected device, the raw ultrasound data, stored in the raw data buffer, corresponding to the one or more images.

**[0029]** In some embodiments, prior to storing the acquired raw ultrasound data in the raw data buffer, the method further involves: receiving direction from the wirelessly connected device that a raw ultrasound data collection mode of the ultrasound machine is to be activated; and activating the raw ultrasound data collection mode.

**[0030]** In some embodiments, prior to receiving the direction from the wirelessly connected device that the raw ultrasound data collection mode is to be activated, the method further involves: operating in an imaging mode where the previously-transmitted processed ultrasound image data is generated, and no corresponding raw ultrasound data is stored in the raw data buffer.

**[0031]** In some embodiments, prior to receiving the direction from the wirelessly connected device that the raw ultrasound data collection mode is to be activated, the method further involves: generating an ultrasound image feed including the previously-transmitted processed ultrasound image data; and transmitting the ultrasound image feed to the wirelessly connected device; and wherein upon receipt of the direction from the wirelessly connected device that the raw ultrasound data collection mode is to be activated, the method further involves: continuing to generate and transmit the ultrasound image feed, the ultrasound image feed comprising the transmitted processed ultrasound image data.

**[0032]** In some embodiments, the ultrasound image feed is continued to be generated and transmitted without substantial delay in transmitting successive frames of the ultrasound image feed to the wirelessly connected device.

**[0033]** In some embodiments, after transmitting the processed ultrasound image data to the wirelessly connected device, the method further involves: receiving direction from the wirelessly connected device to deactivate the raw ultrasound data collection mode; and deactivating the raw ultrasound data collection mode, such that additional raw ultrasound data is acquired for generation of additional

processed ultrasound image data, without storage of the additional raw ultrasound data in the raw data buffer.

**[0034]** In some embodiments, the input indicating the raw ultrasound data collection mode of the ultrasound machine is to be activated includes pressing of a button on a user interface provided on one of the ultrasound machine and the wirelessly connected device, and the received input indicating the raw ultrasound data collection mode of the ultrasound machine is to be deactivated includes a release of the button.

**[0035]** In another broad aspect of the present disclosure, there is provided a system for providing raw ultrasound data. The system includes an ultrasound machine configured to: acquire raw ultrasound data; store the acquired raw ultrasound data in a raw data buffer, wherein the raw data buffer is capable of storing a first time duration of raw ultrasound data; generate processed ultrasound image data from the raw ultrasound data, the processed ultrasound image data requiring less storage capacity than the acquired raw ultrasound data; and transmit the processed ultrasound image data; and a wirelessly connected device configured to: receive processed ultrasound image data from the ultrasound machine, store the processed ultrasound image data in an image display buffer, the image display buffer being capable of storing a second time duration of processed ultrasound image data longer than the first time duration, and wherein the image display buffer simultaneously stores: (i) the received processed ultrasound image data corresponding to the raw ultrasound data stored in the raw data buffer, and (ii) processed ultrasound image data, previously-received at the wirelessly connected device, that has no corresponding raw ultrasound data stored in the raw data buffer; receive input selecting one or more images of the received processed ultrasound image data stored in the image display buffer; and transmit information identifying the selected one or more images to the ultrasound machine; wherein the ultrasound machine is further configured to: identify the raw ultrasound data, stored in the raw data buffer, corresponding to the selected one or more images; and transmit, to the wirelessly connected device, the raw ultrasound data, stored in the raw data buffer, corresponding to the selected one or more images.

**[0036]** For simplicity and clarity of illustration, where considered appropriate, reference numerals may be repeated among the figures to indicate corresponding or analogous elements or steps. In addition, numerous specific details are set forth in order to provide a thorough understanding of the exemplary embodiments described herein. However, it will be understood by those of ordinary skill in the art that the embodiments described herein may be practiced without these specific details. In other instances, certain steps, signals, protocols, software, hardware, networking infrastructure, circuits, structures, techniques, well-known methods, procedures and components have not been described or shown in detail in order not to obscure the embodiments generally described herein.

**[0037]** Furthermore, this description is not to be considered as limiting the scope of the embodiments described herein in any way. It should be understood that the detailed description, while indicating specific embodiments, are given by way of illustration only, since various changes and modifications within the scope of the disclosure will become apparent to those skilled in the art from this detailed description. Accordingly, the specification and drawings are to be regarded in an illustrative, rather than a restrictive, sense.

**[0038]** Referring to FIG. **1**, shown there generally as **100** is an example of an ultrasound system according to at least one embodiment of the present invention. Ultrasound system **100** may be operable to transmit ultrasound energy to a target object, receive ultrasound energy reflected from the target object and generate ultrasound image data based on the reflected ultrasound energy. The ultrasound system **100** may include an ultrasound imaging apparatus **110** communicatively connected with a multi-use electronic display device **120**. A wireless connection **140** may connect ultrasound imaging apparatus **110** with display device **120** to permit the transmission of data and commands between the two.

**[0039]** Ultrasound imaging apparatus **110** may include, for example, a transducer array **102** with a plurality of transducer elements **104**, a transmitter **108**, a receiver **106**, a processor **116**, raw data buffer **112**, and a wireless interface **118**. The imaging apparatus **110** may also generally be referred to as an ultrasound machine, probe, imaging device, and/or scanner herein.

**[0040]** Transducer elements **104** are operable to both emit and receive ultrasound energy. When energized by a transmitter **108**, the transducer elements **104** produce a burst of ultrasound energy. The ultrasound energy produced by transducer array **102** is directed toward a target object. Some of the ultrasound energy is reflected back to transducer array **102** as echo signals. The transducer elements **104** convert the received ultrasound energy into analog electrical signals which are then sent to receiver **106**. Receiver **106** may include various well-known elements for digitizing the received ultrasound energy. The raw digitized ultrasound energy may then be transmitted to processor **116** for various processing steps and/or to be stored in raw data buffer **112**.

**[0041]** Processor **116** may be configured to apply various processing steps to the raw ultrasound data. These processing steps may be implemented in software or hardware. The processing steps may include one or more of the following: beamforming, summing, in-phase and quadrature, envelope detection and/or compression. Processor **116** may also be configured to store raw or partially processed ultrasound data in raw data buffer **112**.

**[0042]** Raw data buffer **112** may be configured to store raw or partially processed ultrasound data. In various embodiments, raw data buffer **112** may be configured as a circular buffer.

**[0043]** Processed ultrasound image data may be provided to wireless interface **118** for transmission to a connected device such as multi-use electronic display device **120** (which, for ease of reference may be referred to simply as "display device" herein). The wireless connection **140** formed between wireless interface **118** and wireless interface **128** may be any conventionally known or future developed wireless communication protocol, such as WiFi™ or WiFi Direct™.

**[0044]** Display device **120** may be a smartphone, table computer, or other suitable display device. Display device **120** may include a display **130**, user input module **132**, image buffer **122**, processor **126**, storage device **124**, and wireless interface **128**. Processed ultrasound image data is received by wireless interface **128** and provided to processor **126**. The processed ultrasound image data may be further processed and stored in image buffer **122** and/or displayed

on display **130**. Input module **132** may receive input (e.g., from a user) to control the operation of imaging apparatus **110**. For example, input may be received through input module **132** to request imaging apparatus **110** to transmit raw ultrasound data from imaging apparatus **110**. The received raw ultrasound data may then be stored in data storage **124**.

**[0045]** In various embodiments, input module **132** may include a touchscreen, a keyboard, a mouse, a voice-activated interface, or other user-machine interfaces now known or later developed.

**[0046]** Raw ultrasound data may include different types of data. For example, the raw ultrasound data may include digitized acoustic signals from individual channels, which is commonly referred to as channel domain or (pre-beamformed) radio frequency (RF) data. The raw ultrasound data may additionally or alternatively include beamformed radio frequency data. Alternatively, or in addition, the raw ultrasound data may include in-phase and quadrature (IQ) data.

**[0047]** Processed ultrasound data may include identifying information that may be used to identify the corresponding raw data. For example, the identifying information may include a frame number, a time stamp, or a universally unique identification number.

**[0048]** Processor **126** may perform one or more processing steps on the processed ultrasound image data to generate an ultrasound image. For example, processor **126** may be operable to combine one or more of the frames generated from the ultrasound image data and/or perform scan conversion.

**[0049]** Data storage **124** can include any one or a combination of volatile memory elements (e.g., random access memory (RAM), such as DRAM, SRAM, etc.) and non-volatile memory elements.

**[0050]** In various embodiments, the display device **120** may receive input to select images of the processed image data for which to retrieve corresponding raw data available on the imaging apparatus **110**. As discussed below, this selection may be performed in different ways. For example, the selection methods may include prospective sampling, or retrospective selection of previously acquired image frames stored in an ultrasound image buffer, and/or in substantially real-time while the images are being transmitted from the imaging apparatus **110** and displayed at the display device **120**. Several methods are described below with reference to FIG. **2**, FIG. **3**, FIG. **6**, and FIG. **8**.

**[0051]** Referring to FIG. **2**, shown there generally as **200**, is a flowchart diagram of a method for acquiring raw data from an ultrasound machine using a wirelessly connected device, in accordance with at least one embodiment of the present invention. The method of FIG. **2** shows interactions between an imaging apparatus **110** and a display device **120** (e.g., as is shown in the FIG. **1**). The various acts shown as being performed the respective processors **116**, **126** on the imaging apparatus **110** and the display device **120**. In discussing the various acts below, reference will also be made to the components of the system shown in FIG. **1**. In various embodiments, the method may be implemented with a different system.

**[0052]** In various embodiments, the system **100** of FIG. **1** may be configured to provide a raw data acquisition mode that, when enabled, configures the imaging apparatus **110** to store raw data when acquiring and generating ultrasound images. When not enabled, the raw data may not be stored. For example, providing a raw data acquisition mode that only stores raw data when enabled may allow the imaging apparatus **110** to operate in a more efficient way when the retrieval of raw data is not required (e.g., by simply processing the raw data into processed image data in real time without saving a copy of the raw data into the raw data buffer for later retrieval). In various embodiments, the activation of the raw data acquisition mode may consist of allocating a raw data buffer and beginning to save ultrasound data into the raw data buffer. The "raw data acquisition mode" may also be referred to as the "raw ultrasound data collection mode" or simply, the "raw data collection mode" herein.

**[0053]** In some embodiments, prior to beginning the method of FIG. **2**, a raw data acquisition mode of the system ultrasound system **100** may be enabled. As discussed below, the raw data acquisition mode may be activated in various ways. For example, this may be done in response to a request from the user. Additionally or alternatively, the raw data acquisition mode may be enabled automatically.

**[0054]** At **202**, raw ultrasound data may be acquired by scanner **110**. The raw ultrasound data may be digitized echo signals received from one or more transmission events. The raw ultrasound data may have some signal processing applied, such as adjustment of gain or filtering. The raw ultrasound data may include data from individual transducer elements **104**. Alternatively or in addition, the raw ultrasound data may include post-beamformed data.

**[0055]** In various embodiments, acquisition settings may be controlled by processor **116**. In some embodiments, acquisition settings are based on control signals received from display device **120**.

**[0056]** At **204**, raw ultrasound data may be stored in a raw data buffer **112**. The raw ultrasound data may be stored with identifying information. The identifying information may include one or more of a frame number, timestamp, and/or other unique identifier.

**[0057]** At **206**, ultrasound data may be processed. Various known or future developed processing steps may be applied. For example, processing steps may include one or more of the following: filtering, envelope detection, log compression, and scan conversion. As the ultrasound data is processed, identifying information may be included or tagged to identify which raw ultrasound data the processed data corresponds to.

**[0058]** In various embodiments, act **204** and act **206** may be performed simultaneously and/or iteratively.

**[0059]** As used herein, the raw ultrasound data may include individual channel radiofrequency data. However, in some embodiments, raw ultrasound data may also include other data after one or more preliminary operations have been performed on the individual channel radiofrequency data (but before the data has been transformed into processed ultrasound image data for transmission to the display device **110**). For example, in various embodiments, raw ultrasound data may additionally or alternatively include beamformed radio frequency data and in-phase and quadrature (IQ) data.

**[0060]** The processed ultrasound image data nay be transmitted by imaging apparatus **110** at act **208** and received by display device **120** at act **210**. For example, the processed ultrasound data may be transmitted between wireless interface **118** and wireless interface **128** using a suitable wireless communication protocol.

**[0061]** At **212**, the processed ultrasound image data received at act **210** may be stored (e.g., in image display buffer **122** shown in FIG. **1**). In some embodiments, the processed ultrasound image data may be provided in standard formats of digital images (e.g., Joint Photographic Experts Group (JPEG), Portable Network Graphics (PNG), or Tag Image File Format (TIFF)) and/or videos (e.g., Motion Picture Experts Group-4 (MP4) or Audio Video Interleave (AVI)).

**[0062]** In various embodiments, the raw data buffer **112** storing the raw data at the imaging apparatus **110** may be capable of storing a first time duration of raw ultrasound data, and the image display buffer **112** storing the processed image data at the display device **120** may be capable of storing a second time duration of processed ultrasound data greater than the first time duration. In other words, the number of images stored in image display buffer **112** at the display buffer **120** may exceed the number of image frames for which raw ultrasound data is stored in raw data buffer **112** on imaging apparatus **110**. The relationship between the raw data buffer **112** and the image buffer **122** is illustrated and discussed in greater detail below with respect to FIG. **4**.

**[0063]** At **214**, the processed ultrasound image data may be displayed (e.g., on display **130** of display device **120**). The ultrasound image data may be displayed such that it is substantially in real-time from acquisition (after accounting for processing and transmission delays). Alternatively, the ultrasound image data may be displayed while the imaging apparatus **110** is not actively acquiring, processing, and transmitting data. In various embodiments, the ultrasound image data may be displayed in a manner substantially similar to when a sequence of images is reviewed in a cine loop.

**[0064]** At **216**, input may be received to select one or more images in image display buffer **122**. For example, the input may be received while ultrasound data acquisition is active. Additionally or alternatively, the input may be received while ultrasound data acquisition is paused or stopped. An example user interface for receiving such input is discussed below with respect to FIG. **3**. Additional example methods for selecting images are described below with reference to FIG. **6**, in relation to the example user interface shown in FIG. **7**.

**[0065]** At **218**, information identifying one or more selected images is transmitted by display device **120**. For example, the identifying information may include one or more frame numbers, timestamps, or unique identifiers. In various embodiments, the identifying information may be retrieved from metadata attached to the displayed processed ultrasound image data.

**[0066]** At **220**, the information identifying one or more selected images may be received by imaging apparatus **110**. In some embodiments, the reception of information identifying on or more selected images may be received while the ultrasound imaging device is still acquiring, processing, and transmitting ultrasound data display device **120**. Additionally or alternatively, the reception of information identifying one or more selected images may be received while the ultrasound imaging device is in a 'Freeze' mode or otherwise not actively acquiring, processing, and transmitting ultrasound data.

**[0067]** At **222**, raw ultrasound data may be identified at the imaging apparatus **110** that corresponds to information identifying one or more selected images. This may include matching the corresponding identifying information stored with the raw ultrasound data in act **204** to the identifying information received from the display device in act **220**. In some embodiments, the identifying information may be cross-referenced from one type to another. For example, the identifying information received at act **220** may include one or more frame numbers and the corresponding raw ultrasound data may identified by a range of timestamps corresponding to the one or more frame numbers.

**[0068]** At **224**, raw ultrasound data corresponding to the selected images may be transmitted by imaging apparatus **110**. In various embodiments, the raw ultrasound data may be transmitted in an uncompressed format. However, in some embodiments, the raw ultrasound data may be compressed so as to allow the raw ultrasound data to be transmitted more quickly.

**[0069]** In various embodiments, the raw ultrasound data may be transmitted using the same wireless communication protocol by which the processed ultrasound image data is transmitted to display device **120** at act **208**. However, in some embodiments, the raw ultrasound data may be transmitted using a different wireless communication protocol by which the processed ultrasound image data is transmitted.

**[0070]** At **226**, raw ultrasound data corresponding to the selected images selected at act **216** may be received by display device **120**. Upon reception, the raw ultrasound data may be stored in data storage **124** of the display device **120**. In various embodiments, the received raw ultrasound data may be further uploaded to a server (e.g., a cloud service) so that it can be accessed by additional users.

**[0071]** Referring to FIG. **3**, shown there generally as **300** is a view of an example graphical user interface for selecting ultrasound image frames for which to retrieve corresponding raw ultrasound data, in accordance with at least one embodiment of the present invention. The graphical user interface may be shown on display **130** of display device **120**. As shown, the graphical interface may include an ultrasound image **310**. The graphical interface may include an interface substantially similar to a screen for reviewing previously acquired and/or displayed ultrasound image data. This may be referred to as cine-review in various scenarios, for example.

**[0072]** The interface may include one or more controls for navigating a time-series of ultrasound image data, e.g., "scrubbing". The interface may include controls for stopping and pausing the playback of images, controlling the speed of playback, selecting a particular image frame, or incrementing or decrementing the frames. For example, the interface may include a slider control **312** that may show a miniature or thumbnail image of individual image frames of the processed ultrasound image data. In another embodiment, the slider control **312** may be provided as a simple line with a moving cursor, and as the moving cursor is moved, different image frames may be updated on the main ultrasound image **310** to show an image frame corresponding to the position of the cursor.

**[0073]** In addition to the conventionally known controls for navigating and controlling the display of ultrasound image cine loops, the user interface may include additional controls **314** for selecting one or more ultrasound images for which to acquire corresponding raw ultrasound data. For example, as illustrated the control **314** is provided as a box which may be expanded (e.g., via a pinch-out gesture) to select the frames for which to retrieve raw ultrasound data

for. The user interface may include indicators **334**, **336**, **338** that convey whether raw ultrasound data is available for a particular ultrasound image frame in the cine-loop. In various embodiments, the raw data availability indicator may include a graphical element such as an icon.

**[0074]** In some embodiments, two or more types of raw ultrasound data may be available. The user interface may have additional indicators to indicate which types of raw ultrasound data are available for a particular ultrasound image frame. For example, the user interface may include RF data indicator **334**, IQ data indicator **336** and B-mode data indicator **338**. In some embodiments, the raw data indicators may be an on/off indicator (e.g., a flag or other graphical element) that indicates whether the data (or a certain type of raw ultrasound data) is available for a given frame. In some embodiments, the raw data indicators indicate for which portion of the entire ultrasound cine that raw data (of one or more raw ultrasound data types) is available. If the example user interface is used to navigate to previously-received ultrasound images for which there is no corresponding raw data available to be retrieved, it may display an image without the indicators **334**, **336**, **338** for those frames to indicate that no corresponding raw ultrasound data is available to be retrieved.

**[0075]** The interface may include a control for selecting one or more ultrasound images for which to acquire corresponding raw ultrasound data. The selection control may, for example, be a button that marks the currently displayed frame for raw data retrieval. The selection control may also be a control that enables the selection of a range of ultrasound image frames. The interface may also include a selection indicator for indicating which ultrasound image frames have been selected. The selection indicator may be separate from the selection control or may be combined. For example, the selection control may be a graphical indicator that changes shape (e.g., the rectangle **314** extending to encompass the selected frames) or color (e.g., so as to provide a highlighting effect) if the currently displayed image frame has been marked for raw ultrasound data retrieval.

**[0076]** The interface may include a control for initiating the raw ultrasound data retrieval process once one or more ultrasound images have been selected. This control may be provided in the form of a physical button on display device **120** or a control on the user interface.

**[0077]** In various embodiments, the number and type of ultrasound data stored in the raw data buffer may influence the duration for which the ultrasound images have corresponding raw data. For example, as noted above, raw ultrasound data may not necessarily just be channel domain or (pre-beamformed) radio frequency (RF) data. In various embodiments, raw ultrasound data may also include beamformed radio frequency data, in-phase and quadrature (IQ) data, and/or unprocessed B-mode data.

**[0078]** For a given image frame, the amount of storage capacity required to store the raw data may be reduced after successive preliminary operations are performed. For example, RF data may require the largest storage per image frame; IQ data may require less storage capacity, and unprocessed B-mode data even less. Given limited storage constraints at the imaging apparatus **110**, since RF data may require the largest storage capacity per image frame, there may correspondingly be fewer image frames of processed image data for which such raw ultrasound data is available. However, for IQ data that requires less storage capacity than RF data, there may be more processed image frames for which IQ data is available. Further, since unprocessed B-mode data may require even less storage capacity than IQ data, there may be even more processed image frames for which unprocessed B-mode data is available.

**[0079]** This may result in an example user interface as is shown in FIG. **3**: where the indicators for each of RF 334, IQ **336**, and unprocessed B-mode **338** raw ultrasound data are positioned beneath the processed image frames for which such respective types of raw ultrasound data is available. The indicators **334**, **336**, **338** increase in number of frames from RF, to IQ, to unprocessed B-mode data to reflect the number of corresponding frames for which such corresponding raw ultrasound data is available. In the illustrated example, there is only 2 frames for which RF data is available, but there are 3 frames for which IQ data is available, and 4 frames for which unprocessed B-mode image data is available. It will be understood that other relationships amongst the different types of raw ultrasound data and their availability may be possible.

**[0080]** Referring to FIG. **4**, shown there generally as **400** is a schematic diagram of the image buffer and raw data buffer of FIG. **1**, in accordance with at least one embodiment of the present invention. This embodiment illustrates a raw data buffer **112** (e.g., as provided on the imaging apparatus **110** shown in FIG. **1**) capable of storing a first time duration of raw ultrasound data and an image buffer **122** (e.g., as provided on the display device **120** shown in FIG. **1**) capable of storing a second time duration of processed ultrasound image data, where the second duration is greater than the first duration.

**[0081]** Raw data buffer **112** may be configured to store a number of raw ultrasound data frames $\mathbf{430}_i$. The raw ultrasound data frames may be identified by a timestamp, a frame number, a universally unique identification number, and/or some other conventionally known or future developed means for determining for which ultrasound image frame the raw data corresponds to. In various embodiments, the size of the raw data buffer may be a fixed or adjustable during operation.

**[0082]** Image buffer **122** may be configured to store a number of ultrasound image frames $\mathbf{420}_i$. The ultrasound image frames may similarly be identified by a timestamp, a frame number, a universally unique identification number, or some other conventionally known and/or future developed means for determining for which raw ultrasound data the image frame corresponds. In various embodiments, the size of image buffer **122** may be a fixed or adjustable during operation.

**[0083]** Raw ultrasound data may require larger storage capacity than the processed ultrasound image frames to which they correspond. Accordingly, for a given image buffer **122** capable of storing a number of processed ultrasound image frames, there may be 'N' frames that can be stored within the image buffer **122**. However, since the storage of the corresponding raw ultrasound data requires more storage capacity, there may be only a subset 'M' of the 'N' processed image frames for which raw ultrasound data is available.

**[0084]** For example, as shown in FIG. **4**, the image buffer **112** may have the capacity to store approximately 20 seconds worth of processed ultrasound image frames (e.g., image frames $\mathbf{420}_1$-$\mathbf{420}_N$). However, since the correspond-

ing raw ultrasound data may require larger storage space, only a subset time duration of time 'T' (e.g., raw ultrasound frames **430**$_1$-**430**$_M$) can be stored in the raw data buffer **112**. As shown in FIG. **4**, processed ultrasound image frames '1', '2', '3' . . . 'M' stored in the image buffer **122** and their corresponding raw ultrasound data (also labeled with corresponding labels '1', '2', '3', . . . 'M') stored in the raw data buffer **112** are shown connected via dotted lines. Whereas the time 'T' only occupied a subset of the full time duration of frames of the image buffer **122**, the same time duration of corresponding raw ultrasound data may occupy substantially all of the raw data buffer **112**.

**[0085]** For example, in one example scenario, the raw data buffer **112** may be configured to store approximately time (T)=5 seconds of raw ultrasound data, which may correspond to a portion of the total time duration of processed ultrasound image frames (e.g., 20 seconds) that can be stored in the image buffer **122**.

**[0086]** Notably, the present embodiments allow for a number of processed ultrasound image frames (e.g., **420**$_{M+1}$-**420**$_N$) to remain stored and accessible in the image buffer **122** even if there they have no corresponding raw ultrasound data to be retrieved from the raw data buffer **112**. These image frames may constitute previously-received processed ultrasound image data that has no corresponding raw ultrasound data stored in the raw data buffer **112**.

**[0087]** Unlike some traditional systems that transfer the raw ultrasound data to the display device **120** automatically upon a 'Freeze' operation, the present embodiments would not need to reserve space in the image buffer **122** to allow for the full breadth of the raw ultrasound data be stored upon automatic transfer. Instead, that space in the image buffer **122** which would otherwise be reserved for storing raw ultrasound data upon automatic transfer can be used to additional processed image frames so that a longer duration of cineloop can be navigated at the display device **120**. By providing a user interface that indicates which subset of the processed ultrasound image frames in the image buffer **122** has corresponding raw data to be retrieved, the present embodiments may provide enhanced flexibility. For example, the present embodiments may allow processed ultrasound images to be generated, transferred, and reviewed in their normal course using the full time duration available with the smaller storage requirements of processed ultrasound image data. At the same time, raw ultrasound data for some of the processed ultrasound image frames may still nevertheless be retrieved upon selection in a suitable user interface (e.g., such as is shown in FIG. **3**).

**[0088]** In further embodiments, the number of image frames stored in image buffer **122** may be restricted to a number smaller than its total capacity, or the image buffer size may be reduced, so that all images in the image buffer have corresponding raw ultrasound data in the raw data buffer. The change in the number of images that that image buffer **122** is configured to store may be changed dynamically, for example by enabling a raw data collection mode.

**[0089]** In the examples noted above, the image frames for which to obtain raw ultrasound data may be selected after they are displayed on display device **120**. To facilitate the identification of the raw data corresponding to the processed ultrasound image frames, raw data availability information may be sent together with the images frames, for example in a meta tag. Additionally or alternatively, raw data availability may be requested from the imaging device **110** in additional communications (not shown) between the imaging apparatus **110** and the display device **120**.

**[0090]** In the embodiments described above, a raw data acquisition mode can be enabled prior to performing the method of FIG. **2**. Raw ultrasound data can then be stored in the raw data buffer **112** as processed ultrasound image data is being generated and transmitted. Using an example user interface such as is shown in FIG. **3**, the display device **120** may then receive input to select which of the processed image frames to retrieve raw ultrasound data for. This may be considered a way of retrospectively retrieving raw ultrasound data after processed ultrasound data has already been transmitted from the imaging apparatus **110** to the display device **120**.

**[0091]** However, in another aspect, the present embodiments may allow for different ways of enabling raw data acquisition mode and/or selecting processed ultrasound image frames for which to retrieve raw ultrasound data. These various aspects of the present embodiments are discussed generally below with respect to the methods shown in FIGS. **5-8**.

**[0092]** Referring to FIG. **5**, shown there generally as **500** is a flowchart diagram of a method for acquiring raw data from an ultrasound machine using a wirelessly connected device, in accordance with at least another embodiment of the present invention. The method of FIG. **5** is a more generalized version of FIG. **2**, where the acts of FIG. **5** with analogous reference numerals to that shown in FIG. **2** may be performed in a substantially similar manner.

**[0093]** The method of FIG. **5** differs from the method of FIG. **2** in at least two ways. First, at **504**, raw ultrasound data is stored in a raw data buffer **112**. However, the raw data buffer may not have any restrictions on the size of the raw data buffer **112**, as there was in act **204** of FIG. **2**. Second, act **212** can be omitted; specifically, there is no requirement to store the processed ultrasound image data in an image buffer, and there is no restriction on the size of the image buffer. As discussed below, different ways of enabling raw data acquisition mode and/or selecting processed ultrasound image frames for which to retrieve raw ultrasound data may be performed with this more generalized method shown in FIG. **5** (e.g., by modifying one or more of the acts).

**[0094]** Referring to FIG. **6**, shown there generally as **600** is a flowchart diagram of certain acts for selecting and retrieving raw ultrasound data, in accordance with at least one embodiment of the present invention. Whereas the methods of FIGS. **2** and **5** have acts **214-216** that first display processed ultrasound image data (act **214**) and then receive input for selecting the one or more images in the image display buffer for which to retrieve raw ultrasound data (act **216**), it may be possible to replace acts **214-216** in these methods with the acts shown in FIG. **6** so that another way of identifying image frames for retrieving raw ultrasound data can be performed. As illustrated, the acts shown in FIG. **6** may be performed by the display device **120** after act **212** of FIG. **2** or after act **210** of FIG. **5**.

**[0095]** At **610**, an image frame of processed ultrasound image data can be displayed on display **130** of display device **120**. Act **610** may be performed in a manner substantially similar to the manner in which act **214** in FIGS. **2** and **5** is performed for displaying images; however, instead of displaying stream of received processed ultrasound images, a single image frame is displayed and the method can proceed to act **612**.

**[0096]** At **612**, the method may be configured to monitor for input that marks the displayed image for selection. For example, the input may be received via input module **132** on display device **120** (e.g., as is shown in FIG. **1**). In an example embodiment, the input may be received via a button on a user interface that can be pressed as processed ultrasound image frames are continually being displayed. If such a button is pressed (or held down) while a processed ultrasound image is being displayed, that can be considered the input for marking an image for selection at act **612**. If no input is received, the ultrasound system returns to act **610** to display the next image.

**[0097]** If the input to mark an image for selection is received at act **612**, the method may proceed to act **614** to mark the currently displayed frame for a raw data retrieval. The current frame may be marked by reading and storing identifying information of the ultrasound image (e.g., frame number, timestamp, and/or other suitable identifying information—as discussed above). Additionally or alternatively, the marked frame may also be stored in a separate image buffer. In some embodiments, marking the currently displayed image may additionally or alternatively involve sending a save request to the imaging apparatus **110**. The save request may prevent the raw ultrasound data corresponding to the current frame in the raw data buffer from being overwritten. After marking a current image for selection to retrieve corresponding raw ultrasound data, the method may proceed to act **616**.

**[0098]** At **616**, the method may involve monitoring for input to transmit a request for retrieving raw ultrasound data of any images(s) marked for selection. If no input is received, the method may return to act **214** to continue displaying subsequent image frames of the processed ultrasound image data and monitoring for input that marks displayed processed image frames for retrieving corresponding raw ultrasound data. If input is received, the method may proceed to act **218** of the methods of FIG. **2** or **5**, and information identifying the one or more selected images can be transmitted to the imaging apparatus **110**.

**[0099]** The input received at act **216** may differ in various embodiments. For example, input may be provided in the form of a 'Retrieve' button on a user interface that is enabled once at least one frame is marked for selection. If pressed, this may allow the method to proceed to act **218**, as noted. In another embodiment, the pressing of a 'Freeze' button on a user interface may constitute the input for act **216**. Since the pressing of a 'Freeze' button may stop transmittal of processed ultrasound image data to the display device **120**, bandwidth in the communication link between the imaging apparatus **110** and the display device **120** may be freed up so as to allow the raw ultrasound data for the selected image frames to be provided to the display device **120**. Unlike the embodiment discussed above with respect to FIG. **3** where a user interface allows for selection of processed ultrasound image frames for retrieving raw ultrasound data retrospectively after the processed ultrasound image frames are displayed, the acts of FIG. **6** allow for marking of processed ultrasound images for selection as they are being displayed. The acts of FIG. **6** may thus be considered a method of prospectively selecting the processed ultrasound images for which to retrieve raw ultrasound data.

**[0100]** In certain instances, the acts of FIG. **6** may be considered a method of selecting the image frames for which to obtain raw ultrasound data in substantially real-time to when they are displayed. As noted, during the real-time display of images, the display device **120** may receive an input from the user to request raw ultrasound data for the current frame. Pressing the raw data button on the use interface 'marks' the current image frame. (e.g. saves the timestamp). Once imaging is stopped (e.g. through 'Freeze' button push), the list of timestamps is sent to the probe to retrieve the raw data.

**[0101]** Referring to FIG. **7**, shown there generally as **700** is a view of a graphical user interface for retrieving raw ultrasound data, in accordance with at least one embodiment of the present invention. The graphical user interface may be shown on display **130** of user interface device **120** and may include an ultrasound image **710**. The ultrasound image **710** may be a live stream of images transmitted from the imaging apparatus **110** and shown substantially in real-time.

**[0102]** The graphical interface may include controls for controlling the ultrasound imaging apparatus **110** (e.g., ultrasound image data acquisition parameters) and interacting with the acquired and displayed ultrasound image(s). For example, a 'Freeze' button **714** (shown as a snowflake icon in FIG. **7**) may be used to start and stop image acquisition, and a capture button **716** may be provided to save the currently displayed image.

**[0103]** The graphical interface may include one or more additional controls for enabling, selecting, and requesting raw ultrasound data. For example, a raw data request button **720** may be provided to mark a currently displayed frame for raw ultrasound data retrieval. An input via this button **720** may, for example, constitute the input to be received at act **612** of FIG. **6**. In various embodiments, the pressing of this button **720** may additionally or alternatively initiate the start of a raw data acquisition mode. For example, as discussed below, this button **720** may constitute the signal being monitored for at act **822** of FIG. **8**.

**[0104]** As discussed above, prior to initiating the methods of FIG. **2** and FIG. **5** the imaging apparatus **110** may have received input to begin operating in a raw data acquisition mode. In various embodiments, the ultrasound system **100** may be operable both in a mode where raw ultrasound data is not stored (e.g., a normal imaging mode) and a mode where raw ultrasound data is stored (e.g., a raw data acquisition mode). Limiting the storage of raw ultrasound data to only the periods when it is required may help conserve battery power. This may allow the imaging apparatus **110** to operate more efficiently since it does not need to allocate the raw data buffer **112** for storing raw ultrasound data of processed ultrasound images. In various embodiments, the raw data acquisition mode can be explicitly enabled (e.g., in a settings menu of a software application configured to communicate with the imaging apparatus **110**). FIG. **8** illustrates a method where a raw ultrasound data acquisition mode can be prospectively enabled as processed ultrasound images are being displayed at the display device **120**.

**[0105]** Referring to FIG. **8**, shown there generally as **800** is a flowchart diagram of a method for acquiring raw data from an ultrasound machine using a wirelessly connected device, in accordance with at least another embodiment of the present invention. In this embodiment, ultrasound system **100** is operable in both a normal imaging mode and a raw data acquisition mode. The method of FIG. **8** may also provide prospective automated selection of the image frames for which to acquire and transmit corresponding raw ultrasound data.

**[0106]** In the method of FIG. **8**, ultrasound system **100** may start in a normal imaging mode. Acts **202**, **206**, **208**, **210** and **214** in FIG. **8** may be performed in a manner similar to the way acts **202**, **206**, **208**, **210** and **214**, respectively, were described as being performed with reference to FIG. **2**. However, in this embodiment, raw ultrasound data is not stored at this stage of operation.

**[0107]** At **816**, input may be received to start raw ultrasound data storage at the display device **120** (e.g., to enable raw data acquisition mode), and a signal may be transmitted to start raw ultrasound data storage at act **818**. The transmission of the signal at act **818** may be considered an example of the display device **120** directing the imaging apparatus **110** to activate the raw ultrasound data collection mode at the imaging apparatus **110**. The input may be received through input module **132** at display device **120** (as shown in FIG. **1**). For example, as noted above, the user interface control **720** described with reference to FIG. **7** may be used.

**[0108]** At **820**, imaging apparatus **110** may check if a signal to start raw ultrasound data storage was received. At **822**, if a signal to start raw ultrasound data storage was received at act **820**, imaging apparatus **110** may switch to operate in a raw data acquisition mode (the 'YES' branch at **822**). If a signal to start raw ultrasound storage was not received, imaging apparatus **110** may continue to operate in the normal imaging mode and return to acquire raw ultrasound data at act **202** (the 'NO' branch at **822**).

**[0109]** While operating in raw data acquisition mode, imaging apparatus **110** may perform act **202** and **204** in a manner similar to act **202** and **204** described with reference to FIG. **2**.

**[0110]** At **824**, the stored raw ultrasound data may be marked for selection. In this embodiment, no secondary selection process on the display device may be necessary. Various criteria may be used to select which raw ultrasound data are marked for selection. In some embodiments, substantially all raw ultrasound data acquired while operating in raw data acquisition mode may be marked for selection. In other embodiments, predetermined criteria may be used to select a subset of the acquired raw ultrasound data. For example, the predetermined criteria may indicate that every $n^{th}$ frame is to be stored (where 'n' is a positive integer) so as to allow raw ultrasound data to be stored over a longer time duration (given a limited size of raw data buffer **112**).

**[0111]** After act **824**, method **800** of FIG. **8** may continue to perform acts **206**, **208**, **210** and **214** in a manner similar to acts **206**, **208**, **210** and **214** as described with reference to FIG. **2** to acquire, process, transmit, and display processed ultrasound image data on display device **120**. Imaging apparatus **110** may continue to acquire, store, and transmit processed ultrasound image data until a signal to stop raw ultrasound data storage is received.

**[0112]** At **836**, input may be received to stop raw ultrasound data storage. The input may be received via input module **132** on display device **130**, for example. Alternatively, an input may be received based on the state of the display device **120**. For example, raw ultrasound data storage may be stopped after a predetermined time has been reached, a certain number of frames have been acquired, and/or a certain volume of raw ultrasound data has been acquired. These thresholds on time, number of frames, and/or data volume may be configured or selected by the user, in various embodiments.

**[0113]** In some embodiments, the input to stop raw ultrasound data storage may also stop the acquisition, processing, transmission, and display of processed ultrasound image data. For example, a 'Freeze' control may be used to freeze imaging and also stop raw ultrasound data storage.

**[0114]** At **838**, the signal to stop raw ultrasound data storage can be transmitted from display device **120** to imaging apparatus **110**. The transmission of the signal at act **838** may be considered the display device directing the imaging apparatus **110** to deactivate the raw ultrasound data collection mode.

**[0115]** At **840**, imaging apparatus **110** may check to see if a stop raw ultrasound data storage signal was received from display device **120**. At **842**, if a stop raw ultrasound data storage signal was not received at act **840**, the imaging apparatus **110** may continue to acquire ultrasound data at act **202** (the 'NO' branch at **842**). If a stop raw ultrasound data storage signal was received, imaging apparatus **110** continues to act **844** (the 'YES' branch at **842**).

**[0116]** At **844**, the marked raw ultrasound data can be transmitted to display device **120** (e.g., using the connection **140** shown in FIG. **1**). At **846**, the raw ultrasound data may be received from the imaging apparatus **110**. Upon receipt, the selected raw ultrasound data may be stored in data storage **124**. The method of FIG. **8** may provide a simplified example embodiment where the raw data acquisition mode and the marking of processed ultrasound images can be prospectively performed with a single user interface control. For example, this may reduce the number of navigational steps needed to obtain raw ultrasound data for desired processed image frames, and thereby enhance ease and simplicity of operation. In some instances, the method of FIG. **8** may also be considered to be selecting processed ultrasound image(s) for raw data acquisition in substantially real-time while processed ultrasound images are being transmitted from the imaging apparatus **110** and displayed at the display device **120**.

**[0117]** The generation and transmission of processed ultrasound images in the normal imaging mode may be considered the generation and transmission of an ultrasound image feed of processed ultrasound images for display at the display device **120**. In various embodiments, when input to activate a raw data collection mode is received at act **816** and transmitted to the imaging apparatus **110** at act **818**, the imaging apparatus **110** may continue to generate and transmit the ultrasound image feed, and the processed ultrasound images being transmitted and received at acts **208** and **210** during the raw data collection mode may be considered part of the same ultrasound image feed.

**[0118]** In various embodiments, the signal to start the raw data acquisition mode transmitted at act **818** can be configured to be lightweight and small in size. This may allow the signal to be transmitted to the imaging apparatus **110** without consuming much bandwidth in the communication link **140**. The lightweight nature of the signal may also allow the signal to be received by the imaging apparatus **110** without the imaging apparatus **110** incurring much processing overhead. As a result, the imaging apparatus **110** may be able to transition into the raw data collection mode without causing substantial delay in the generation and transmission of the ultrasound image feed. The viewing of the ultrasound image feed at the display device **120** may likewise proceed without substantial delay in displaying successive frames of the ultrasound image feed.

**[0119]** The method of FIG. **8** may be considered an instance where the imaging device **110** can be instructed to acquire raw ultrasound data for a number of frames before the imaging frames have been acquired. For example, the imaging device **110** may be instructed to acquire one or more ultrasound image frames and to store one or more sets of ultrasound data corresponding to the image frames as the raw ultrasound data is being acquired and processed into processed ultrasound image frames.

**[0120]** In the embodiments described above where selection of processed images may be performed prospectively (e.g., FIG. **6** or FIG. **8**), it may be possible to configure the storage of raw ultrasound data to be performed according to a predetermined criterion while a user interface control is being activated. For example, the selection of one or more frames may be requested based on the following: a certain number of frames (e.g., 10 frames), a certain time frame (e.g., 10 seconds), and/or a proportion of available storage capacity (e.g., 75% of the raw data buffer **112**, or 50% of data storage **124**). In another example of a predetermined criteria, the frames for which raw ultrasound data is stored need not be contiguous. For example, raw ultrasound data may be stored for every $j^{th}$ image frame (e.g., where j is a positive integer greater than 1), or every k seconds (e.g., where k is a positive number greater than 0).

**[0121]** Referring to FIG. **9**, shown there generally as **900** is a data flow diagram of FIG. **9** is a data flow diagram of a method for selecting and retrieving raw ultrasound data from an ultrasound machine using a wirelessly connected device, in accordance with at least one embodiment of the present invention. FIG. **9** shows how raw ultrasound data of various types and forms (e.g., as discussed above, after various preliminary operations have been performed) may be stored in raw data buffer **112**. Some elements that were previously shown in FIG. **1** are also referred to in FIG. **9**.

**[0122]** Reflected ultrasound energy may be converted into electrical energy by transducer **102** and digitized by receiver **106**. The digitized data may then have several preliminary operations applied. The digitized data may be beamformed in beamformer **908**, and then demodulated into in-phase and quadrature data in IQ demodulator **910**. Additional preliminary operations such as forming into a B-mode image by B-Mode operations **912**, filtering in filter **914** and/or additional image processing in image processor **916** may be performed.

**[0123]** Processor **116** may store ultrasound data to raw data buffer **112** after any one or more of the preliminary operations. For example, pre-beamformed channel data from receiver **106** may be stored in raw data buffer **112**. In another example, beamformed data from beamformer **908** and/or corresponding IQ data from IQ demodulator **910** may be stored in raw data buffer **112**. Further, data after B-mode operations have been performed may also be stored in raw data buffer **112**. When more than one type of raw ultrasound data is stored, the data may be stored together or they may be stored separately.

**[0124]** Processed ultrasound image data may be transmitted from wireless interface **118** to wireless interface **128** via communication link **140**. Once received at the wireless interface **128**, the processed ultrasound image data may be provided to processor **126**, and subsequently to post processor **926** so that additional processing steps (e.g., scan conversion) can be applied. The processed ultrasound image data may be buffered in image buffer **122** and displayed on display **130**.

**[0125]** Pursuant to the discussion above, processor **126** may make a request to processor **116** for raw ultrasound data. Processor **116** may retrieve the requested raw ultrasound data from raw data buffer **112** and transmit the selected raw ultrasound data through wireless interface **118** to wireless interface **128**. The retrieved raw ultrasound data may then be stored in data storage **124**.

**[0126]** In various embodiments, greater or fewer of the preliminary operations may be completed on the display device **120**. For example, in some embodiments, B-mode operations **912**, filter **914**, and image processor **916** may be implemented on the display device **120** such that beamformed RF data and/or IQ data is transmitted when a request for raw ultrasound data is made.

**[0127]** As will be appreciated upon reading this description, the apparatus, systems and methods described herein may help to alleviate some drawbacks of traditional ultrasound systems. The embodiments described herein may enable an ultrasound operator to retrieve raw ultrasound data corresponding from a wireless ultrasound probe which corresponds to displayed ultrasound image data. For example, an ultrasound operator may select one or more ultrasound images within a cine loop and retrieve the corresponding raw ultrasound data from a wirelessly connected probe. The present embodiments may enable a higher frame rate and image quality for real-time image display than if raw ultrasound data was attempted to be transmitted simultaneously. Further, the embodiments described herein may provide the advantage of access to raw ultrasound data for more advanced processing or research while still benefiting from the advantages of a wireless probe such as improved ergonomics.

**[0128]** While a number of exemplary aspects and embodiments have been discussed above, those of skill in the art will recognize that may be certain modifications, permutations, additions and sub-combinations thereof. While the above description contains many details of example embodiments, these should not be construed as essential limitations on the scope of any embodiment. Many other ramifications and variations are possible within the teachings of the various embodiments.

## INTERPRETATION OF TERMS

**[0129]** Unless the context clearly requires otherwise, throughout the description and the

**[0130]** "comprise", "comprising", and the like are to be construed in an inclusive sense, as opposed to an exclusive or exhaustive sense; that is to say, in the sense of "including, but not limited to";

**[0131]** "connected", "coupled", or any variant thereof, means any connection or coupling, either direct or indirect, between two or more elements; the coupling or connection between the elements can be physical, logical, or a combination thereof;

**[0132]** "herein", "above", "below", and words of similar import, when used to describe this specification, shall refer to this specification as a whole, and not to any particular portions of this specification;

**[0133]** "or", in reference to a list of two or more items, covers all of the following interpretations of the word:

any of the items in the list, all of the items in the list, and any combination of the items in the list;

**[0134]** the singular forms "a", "an", and "the" also include the meaning of any appropriate plural forms.

**[0135]** Unless the context clearly requires otherwise, throughout the description and the claims:

**[0136]** Words that indicate directions such as "vertical", "transverse", "horizontal", "upward", "downward", "forward", "backward", "inward", "outward", "vertical", "transverse", "left", "right", "front", "back", "top", "bottom", "below", "above", "under", and the like, used in this description and any accompanying claims (where present), depend on the specific orientation of the apparatus described and illustrated. The subject matter described herein may assume various alternative orientations. Accordingly, these directional terms are not strictly defined and should not be interpreted narrowly.

**[0137]** Embodiments of the invention may be implemented using specifically designed hardware, configurable hardware, programmable data processors configured by the provision of software (which may optionally comprise "firmware") capable of executing on the data processors, special purpose computers or data processors that are specifically programmed, configured, or constructed to perform one or more steps in a method as explained in detail herein and/or combinations of two or more of these. Examples of specifically designed hardware are: logic circuits, application-specific integrated circuits ("ASICs"), large scale integrated circuits ("LSIs"), very large scale integrated circuits ("VLSIs"), and the like. Examples of configurable hardware are: one or more programmable logic devices such as programmable array logic ("PALs"), programmable logic arrays ("PLAs"), and field programmable gate arrays ("FPGAs"). Examples of programmable data processors are: microprocessors, digital signal processors ("DSPs"), embedded processors, graphics processors, math co-processors, general purpose computers, server computers, cloud computers, mainframe computers, computer workstations, and the like. For example, one or more data processors in a control circuit for a device may implement methods as described herein by executing software instructions in a program memory accessible to the processors.

**[0138]** For example, while processes or blocks are presented in a given order herein, alternative examples may perform routines having steps, or employ systems having blocks, in a different order, and some processes or blocks may be deleted, moved, added, subdivided, combined, and/or modified to provide alternative or subcombinations. Each of these processes or blocks may be implemented in a variety of different ways. Also, while processes or blocks are at times shown as being performed in series, these processes or blocks may instead be performed in parallel, or may be performed at different times.

**[0139]** The invention may also be provided in the form of a program product. The program product may comprise any non-transitory medium which carries a set of computer-readable instructions which, when executed by a data processor (e.g., in a controller and/or ultrasound processor in an ultrasound machine), cause the data processor to execute a method of the invention. Program products according to the invention may be in any of a wide variety of forms. The program product may comprise, for example, non-transitory media such as magnetic data storage media including floppy diskettes, hard disk drives, optical data storage media including CD ROMs, DVDs, electronic data storage media including ROMs, flash RAM, EPROMs, hardwired or preprogrammed chips (e.g., EEPROM semiconductor chips), nanotechnology memory, or the like. The computer-readable signals on the program product may optionally be compressed or encrypted.

**[0140]** Where a component (e.g. a software module, processor, assembly, device, circuit, etc.) is referred to above, unless otherwise indicated, reference to that component (including a reference to a "means") should be interpreted as including as equivalents of that component any component which performs the function of the described component (i.e., that is functionally equivalent), including components which are not structurally equivalent to the disclosed structure which performs the function in the illustrated exemplary embodiments of the invention.

**[0141]** Specific examples of systems, methods and apparatus have been described herein for purposes of illustration. These are only examples. The technology provided herein can be applied to systems other than the example systems described above. Many alterations, modifications, additions, omissions, and permutations are possible within the practice of this invention. This invention includes variations on described embodiments that would be apparent to the skilled addressee, including variations obtained by: replacing features, elements and/or acts with equivalent features, elements and/or acts; mixing and matching of features, elements and/or acts from different embodiments; combining features, elements and/or acts from embodiments as described herein with features, elements and/or acts of other technology; and/or omitting combining features, elements and/or acts from described embodiments.

**[0142]** It is therefore intended that the following appended claims and claims hereafter introduced are interpreted to include all such modifications, permutations, additions, omissions, and sub-combinations as may reasonably be inferred. The scope of the claims should not be limited by the preferred embodiments set forth in the examples, but should be given the broadest interpretation consistent with the description as a whole.

What is claimed is:

**1**. A method for acquiring raw ultrasound data from an ultrasound machine using a wirelessly connected device, the method comprising, at the wirelessly connected device:

receiving processed ultrasound image data from the ultrasound machine, wherein the received processed ultrasound image data corresponds to raw ultrasound data stored in a raw data buffer at the ultrasound machine, wherein the raw data buffer is capable of storing a first time duration of raw ultrasound data, and the received processed ultrasound image data requires less storage capacity than the corresponding raw ultrasound data stored in the raw data buffer;

storing the processed ultrasound image data in an image display buffer, the image display buffer being capable of storing a second time duration of processed ultrasound image data longer than the first time duration, and wherein the image display buffer simultaneously stores: (i) the received processed ultrasound image data corresponding to the raw ultrasound data stored in the raw data buffer, and (ii) previously-received processed ultrasound image data that has no corresponding raw ultrasound data stored in the raw data buffer;

receiving input selecting one or more images of the received processed ultrasound image data stored in the image display buffer;

transmitting information identifying the selected one or more images to the ultrasound machine, wherein the ultrasound machine identifies the raw ultrasound data, stored in the raw data buffer, that corresponds to the selected one or more images, for return to the wirelessly connected device; and

receiving the identified raw ultrasound data corresponding to the selected one or more images.

**2**. The method of claim **1**, wherein (i) the received processed ultrasound image data corresponding to the raw ultrasound data stored in the raw data buffer at the ultrasound machine and (ii) the previously-received processed ultrasound image data stored in the image display buffer are viewable in a user interface of the wirelessly connected device that navigates images stored in the image display buffer.

**3**. The method of claim **2**, wherein prior to receiving input selecting the one or more images, the user interface is configured to display an image of the received processed ultrasound image data, and wherein the user interface indicates that corresponding raw ultrasound data is available to be retrieved from the ultrasound machine.

**4**. The method of claim **2**, wherein prior to receiving input selecting the one or more images, the user interface is configured to display an image from the previously-received processed ultrasound image data, and wherein the user interface does not indicate that corresponding raw ultrasound data is available to be retrieved from the ultrasound machine.

**5**. The method of claim **1**, further comprising:

storing the received raw ultrasound data, corresponding to the selected one or more images, in a storage location different from the image display buffer.

**6**. The method of claim **1**, wherein prior to receiving the processed ultrasound image data, the method further comprises:

receiving input indicating a raw ultrasound data collection mode of the ultrasound machine is to be activated; and

directing the ultrasound machine to activate the raw ultrasound data collection mode.

**7**. The method of claim **6**, wherein prior to receiving the input indicating the raw ultrasound data collection mode is to be activated, the method further comprises:

operating in an imaging mode where the previously-received processed ultrasound image data is received, and no corresponding raw ultrasound data is stored in the raw data buffer at the ultrasound machine.

**8**. The method of claim **6**, wherein prior to receiving the input indicating the raw ultrasound data collection mode of the ultrasound machine is to be activated, the method further comprises:

receiving an ultrasound image feed comprising the previously-received processed ultrasound image data; and

displaying the ultrasound image feed;

and wherein during receipt of the input indicating the raw ultrasound data collection mode at the ultrasound machine is to be activated, the method further comprises:

continuing to receive and display the ultrasound image feed, the ultrasound image feed comprising the received processed ultrasound image data.

**9**. The method of claim **8**, wherein the ultrasound image feed is continued to be received and displayed when the raw ultrasound data collection mode is activated without substantial delay in displaying successive frames of the ultrasound image feed.

**10**. The method of claim **6**, wherein after the received processed ultrasound image data is stored in the image display buffer, the method further comprises:

receiving input indicating the raw ultrasound data collection mode of the ultrasound machine is to be deactivated; and

directing the ultrasound machine to deactivate the raw ultrasound data collection mode.

**11**. The method of claim **10**, wherein the input indicating the raw ultrasound data collection mode of the ultrasound machine is to be activated comprises pressing of a button on a user interface provided on one of the ultrasound machine and the wirelessly connected device, and the received input indicating the raw ultrasound data collection mode of the ultrasound machine is to be deactivated comprises a release of the button.

**12**. The method of claim **1**, wherein prior to receiving the input selecting one or more images from the received processed ultrasound image data stored in the image display buffer, the method further comprises:

receiving input to stop ultrasound data acquisition at the ultrasound machine; and

directing the ultrasound machine to stop ultrasound data acquisition.

**13**. A method for transmitting raw ultrasound data from an ultrasound machine to a wirelessly connected device, the method comprising, at the ultrasound machine:

acquiring raw ultrasound data;

storing the acquired raw ultrasound data in a raw data buffer, wherein the raw data buffer is capable of storing a first time duration of raw ultrasound data;

generating processed ultrasound image data from the raw ultrasound data, the processed ultrasound image data requiring less storage capacity than the acquired raw ultrasound data;

transmitting the processed ultrasound image data to the wirelessly connected device, wherein the transmitted processed ultrasound image data is stored at the wirelessly connected device in an image display buffer, the image display buffer being capable of storing a second time duration of processed ultrasound image data longer than the first time duration, and wherein the image display buffer simultaneously stores: (i) the transmitted processed ultrasound image data corresponding to the raw ultrasound data stored in the raw data buffer, and (ii) previously-transmitted processed ultrasound image data that has no corresponding raw ultrasound data stored in the raw data buffer;

receiving, from the wirelessly connected device, information identifying one or more images selected from the transmitted processed ultrasound image data;

identifying the raw ultrasound data, stored in the raw data buffer, corresponding to the one or more images; and

transmitting, to the wirelessly connected device, the raw ultrasound data, stored in the raw data buffer, corresponding to the one or more images.

**14**. The method of claim **13**, wherein prior to storing the acquired raw ultrasound data in the raw data buffer, the method further comprises:

receiving direction from the wirelessly connected device that a raw ultrasound data collection mode of the ultrasound machine is to be activated; and

activating the raw ultrasound data collection mode.

**15**. The method of claim **14**, wherein prior to receiving the direction from the wirelessly connected device that the raw ultrasound data collection mode is to be activated, the method further comprises:

operating in an imaging mode where the previously-transmitted processed ultrasound image data is generated, and no corresponding raw ultrasound data is stored in the raw data buffer.

**16**. The method of claim **14**, wherein prior to receiving the direction from the wirelessly connected device that the raw ultrasound data collection mode is to be activated, the method further comprises:

generating an ultrasound image feed comprising the previously-transmitted processed ultrasound image data; and

transmitting the ultrasound image feed to the wirelessly connected device;

and wherein upon receipt of the direction from the wirelessly connected device that the raw ultrasound data collection mode is to be activated, the method further comprises:

continuing to generate and transmit the ultrasound image feed, the ultrasound image feed comprising the transmitted processed ultrasound image data.

**17**. The method of claim **16**, wherein the ultrasound image feed is continued to be generated and transmitted without substantial delay in transmitting successive frames of the ultrasound image feed to the wirelessly connected device.

**18**. The method of claim **14**, wherein after transmitting the processed ultrasound image data to the wirelessly connected device, the method further comprises:

receiving direction from the wirelessly connected device to deactivate the raw ultrasound data collection mode; and

deactivating the raw ultrasound data collection mode, such that additional raw ultrasound data is acquired for generation of additional processed ultrasound image data, without storage of the additional raw ultrasound data in the raw data buffer.

**19**. The method of claim **18**, wherein the input indicating the raw ultrasound data collection mode of the ultrasound machine is to be activated comprises pressing of a button on a user interface provided on one of the ultrasound machine and the wirelessly connected device, and the received input indicating the raw ultrasound data collection mode of the ultrasound machine is to be deactivated comprises a release of the button.

**20**. A system for providing raw ultrasound data, comprising:

an ultrasound machine configured to:

acquire raw ultrasound data;

store the acquired raw ultrasound data in a raw data buffer, wherein the raw data buffer is capable of storing a first time duration of raw ultrasound data;

generate processed ultrasound image data from the raw ultrasound data, the processed ultrasound image data requiring less storage capacity than the acquired raw ultrasound data; and

transmit the processed ultrasound image data; and

a wirelessly connected device configured to:

receive processed ultrasound image data from the ultrasound machine,

store the processed ultrasound image data in an image display buffer, the image display buffer being capable of storing a second time duration of processed ultrasound image data longer than the first time duration, and wherein the image display buffer simultaneously stores: (i) the received processed ultrasound image data corresponding to the raw ultrasound data stored in the raw data buffer, and (ii) processed ultrasound image data, previously-received at the wirelessly connected device, that has no corresponding raw ultrasound data stored in the raw data buffer;

receive input selecting one or more images of the received processed ultrasound image data stored in the image display buffer; and

transmit information identifying the selected one or more images to the ultrasound machine;

wherein the ultrasound machine is further configured to:

identify the raw ultrasound data, stored in the raw data buffer, corresponding to the selected one or more images; and

transmit, to the wirelessly connected device, the raw ultrasound data, stored in the raw data buffer, corresponding to the selected one or more images.

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| 专利名称(译) | 用于使用无线连接设备从超声机器获取原始超声数据的系统和方法 | | |
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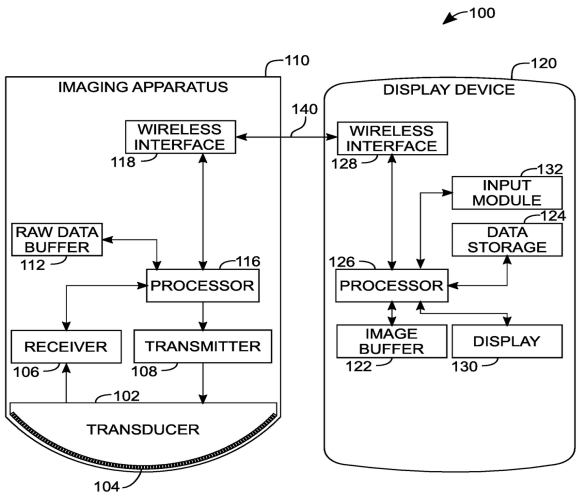
摘要(译)

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