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(54) STAND-ALONE CW DOPPLER PROBE INTERFACE FOR PHASED ARRAY ULTRASOUND SYSTEM

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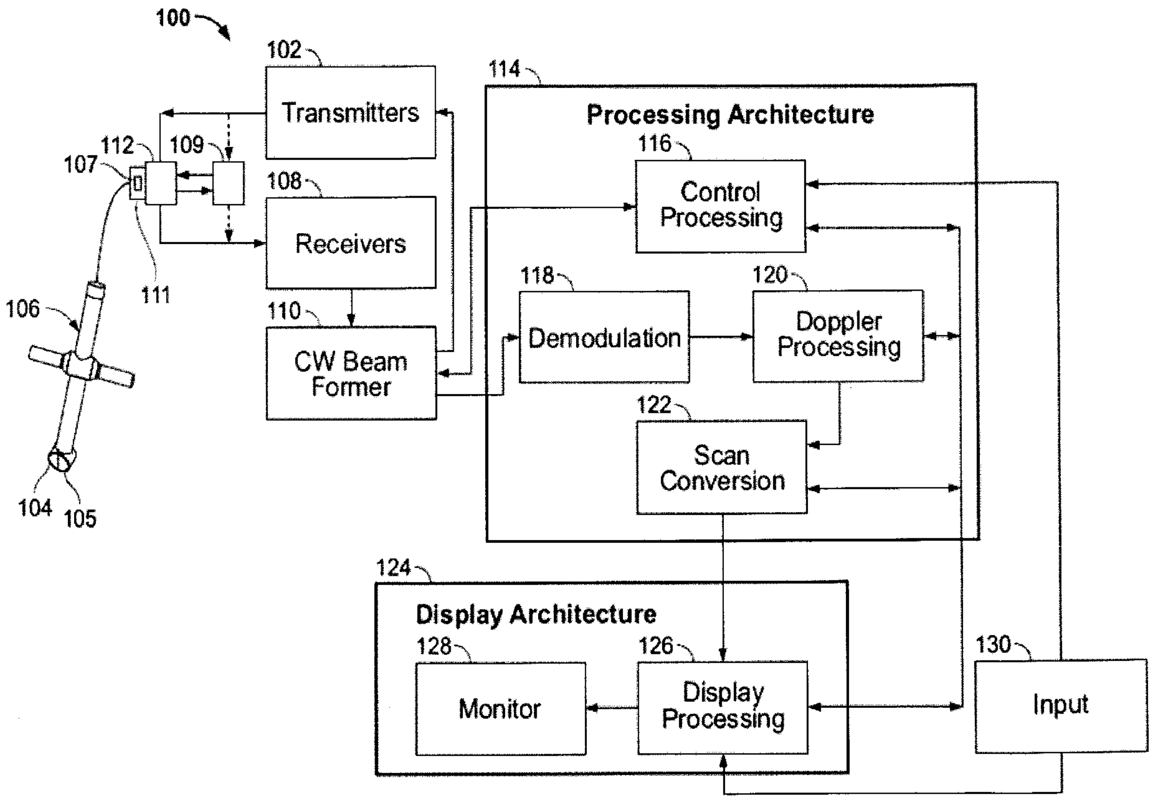
(57) ABSTRACT

A stand-alone continuous wave (CW) Doppler probe (CW probe) comprises a scanning end that has a single transmit element and a single receive element. A connector has probe connecting elements configured to interface with port connecting elements of a probe port that is provided on an ultrasound system. The port connecting elements are configured to connect with system channels of the ultrasound system. Transmit circuitry connects a first set of the probe connecting elements in parallel, and the transmit circuitry is interconnected with the transmit element. Receive circuitry connects a second set of the probe connecting elements in parallel, and the receive circuitry is interconnected with the receive element.



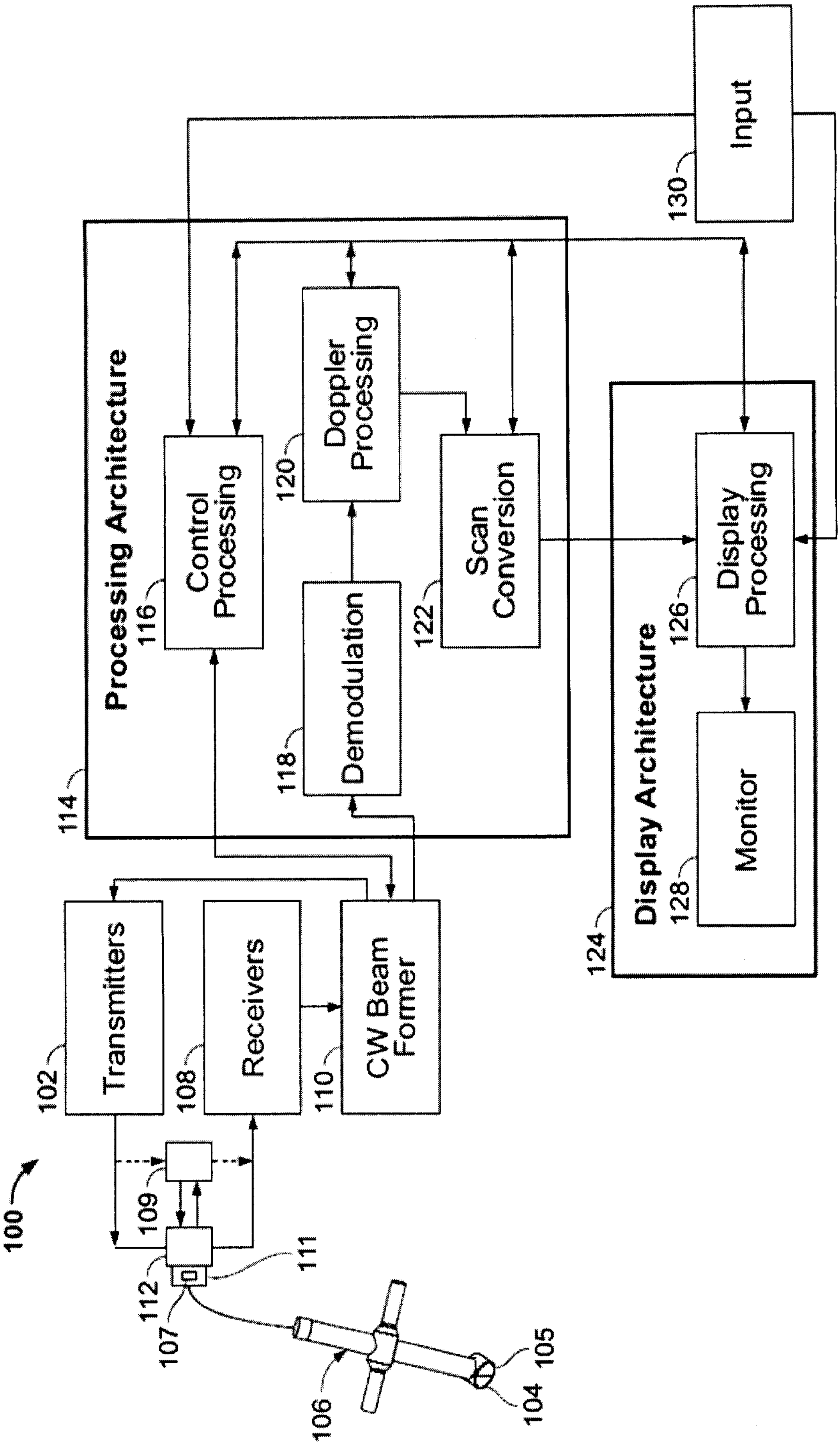

100
Transmitters
Receivers
CW Beam Former
Processing Architecture
Control Processing
Demodulation
Doppler Processing
Scan Conversion
Display Architecture
Display Processing
Monitor
Input
102
104
105
106
107
108
109
110
111
112
114
116
118
120
122
124
126
128
130

FIG. 1

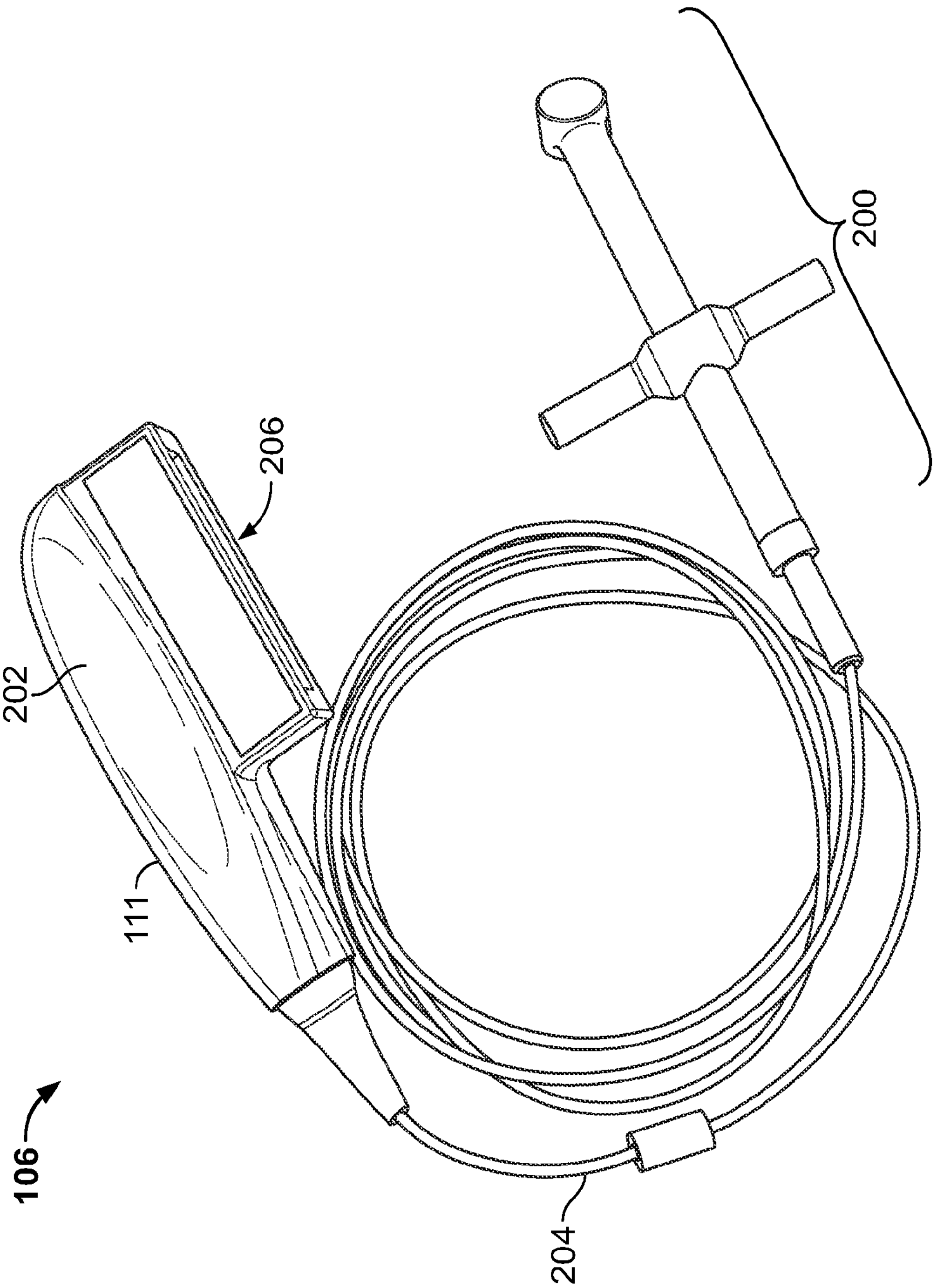
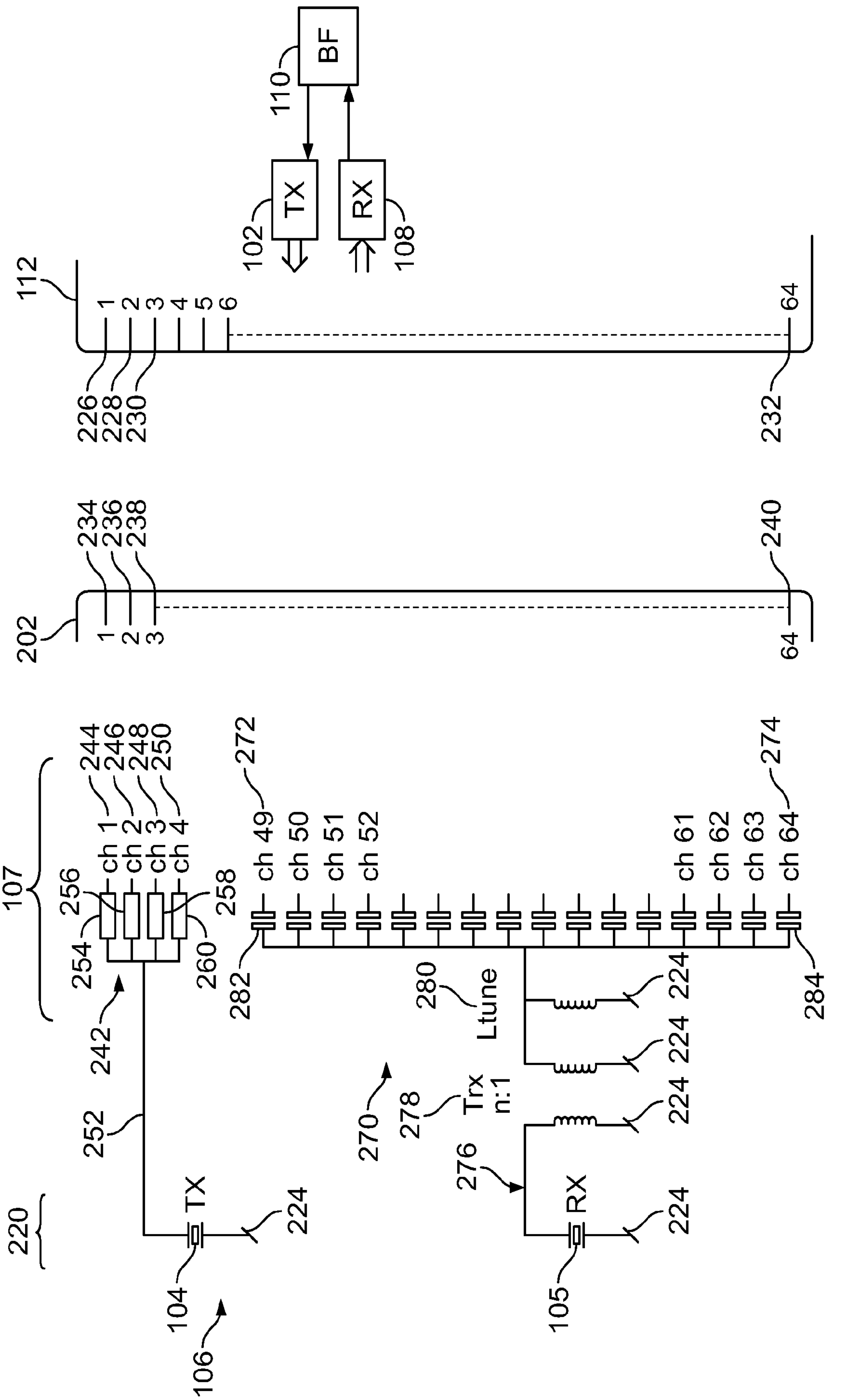


FIG. 2



BF
110
TX
102
RX
108
112
1
2
3
4
5
6
64
226
228
230
232
202
234
236
238
240
107
244
246
248
250
ch 1
ch 2
ch 3
ch 4
256
258
254
260
242
272
ch 49
ch 50
ch 51
ch 52
ch 61
ch 62
ch 63
ch 64
274
282
284
280
Ltune
224
270
278
Trx
n:1
276
RX
105
252
TX
104
106
220

FIG. 3

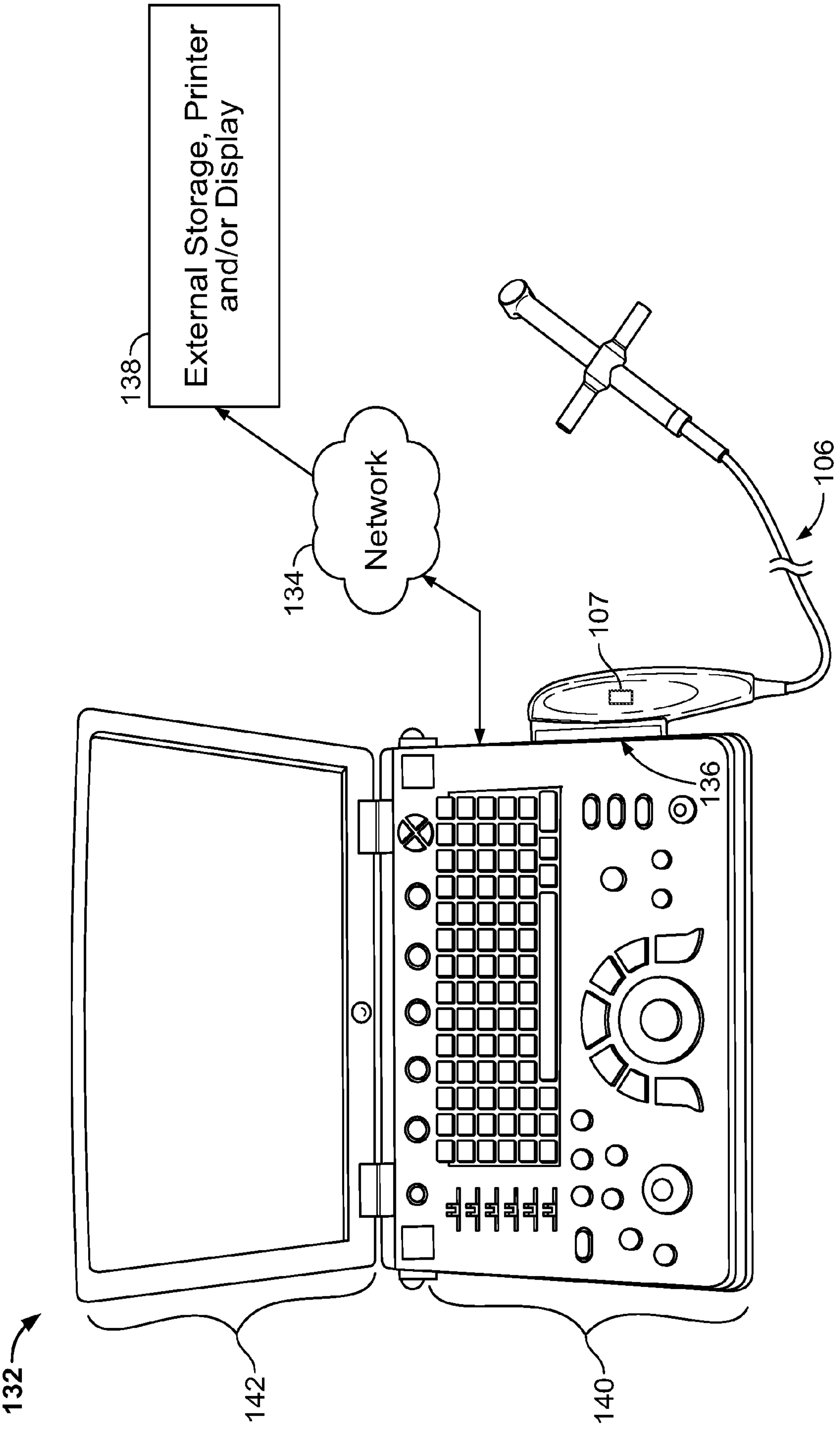

External Storage, Printer and/or Display
138
Network
134
106
107
136
132
142
140

FIG. 4

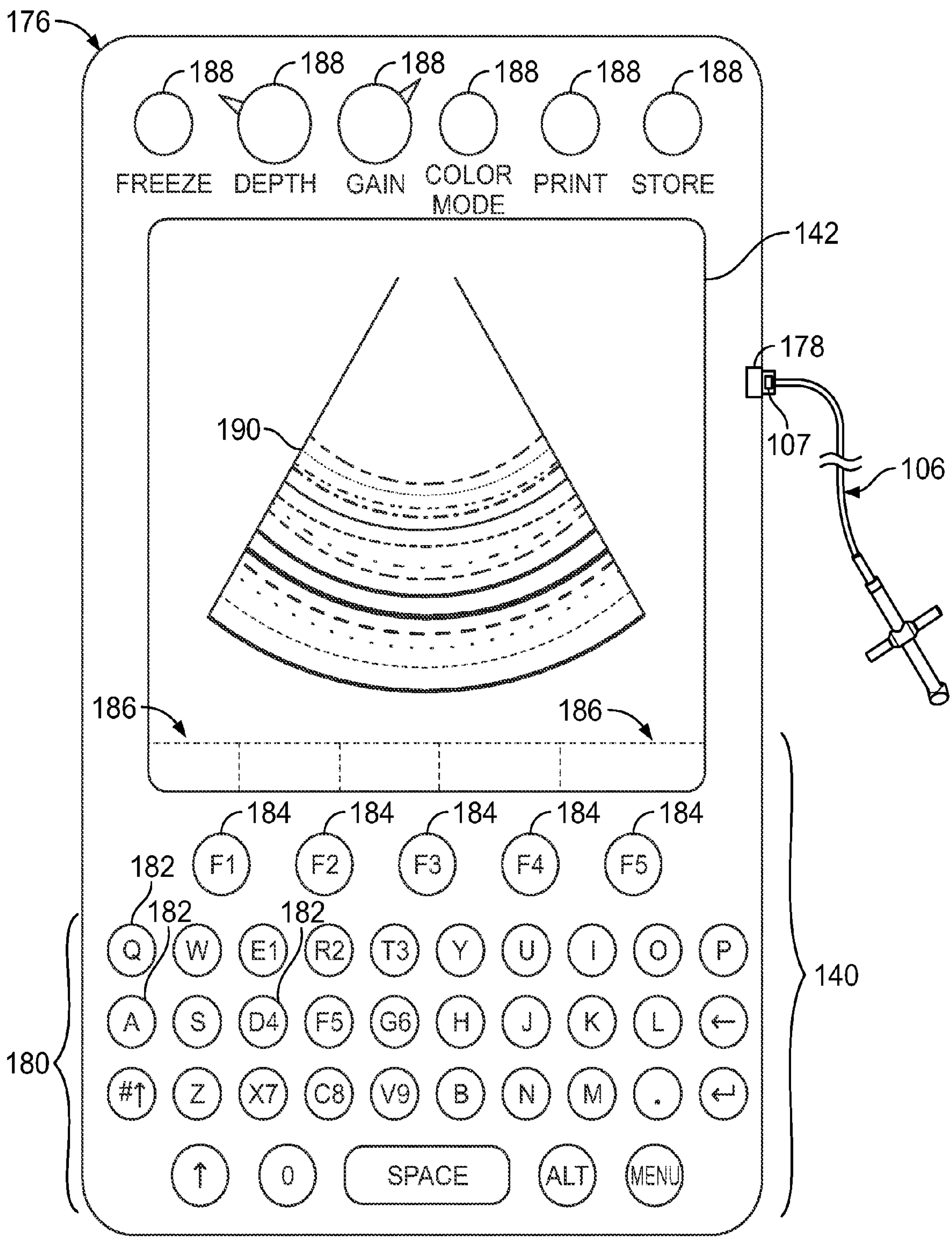

176
188
188
188
188
188
188
FREEZE
DEPTH
GAIN
COLOR MODE
PRINT
STORE
142
178
107
106
190
186
186
184
184
184
184
184
F1
F2
F3
F4
F5
182
182
182
Q
W
E1
R2
T3
Y
U
I
O
P
A
S
D4
F5
G6
H
J
K
L
#↑
Z
X7
C8
V9
B
N
M
.
↑
0
SPACE
ALT
MENU
140
180

FIG. 5

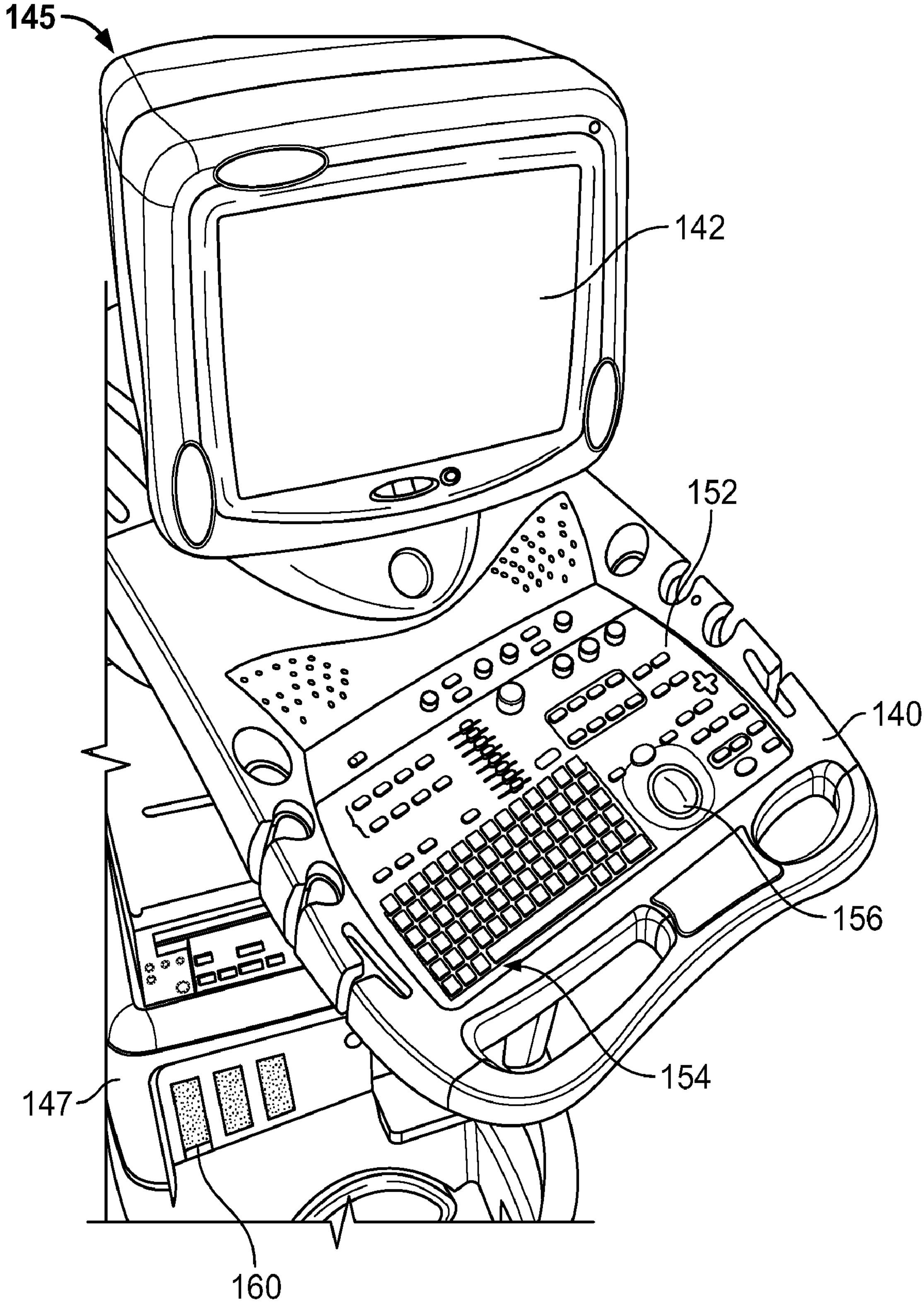


FIG. 6

STAND-ALONE CW DOPPLER PROBE INTERFACE FOR PHASED ARRAY ULTRASOUND SYSTEM

BACKGROUND OF THE INVENTION

[0001] This invention relates generally to ultrasonic imaging, and more particularly to continuous wave (CW) Doppler ultrasound probes.

[0002] A CW Doppler probe may be used for evaluation of blood flow, for example in the human heart. CW Doppler probes have two transducer elements that are typically arranged as a split disc with one element used as an ultrasonic wave transmitter and the other element functioning as a reflected wave receiver. Blood flow information is obtained without obtaining imaging data. The CW Doppler probe has increased sensitivity relative to a phased array probe used for imaging, and it may be desirable to use the CW Doppler probe in anatomical positions when it is difficult to obtain satisfactory images with a phased array probe.

[0003] The CW Doppler probe has some operational requirements that are different than phased array probes. The CW Doppler probe requires a larger transmit current and a lower receiver noise floor than typically available from a single ultrasound system channel as provided through the port for the phased array probes. Therefore, the system provides a separate port for the CW Doppler probe and the system houses the components that are needed to operate the CW Doppler probe. Therefore, the CW Doppler probe can only be used with systems having the optional hardware and probe port installed. In addition, as systems become smaller, less room is available for a dedicated CW Doppler probe port, as well as the required additional circuitry. For example, with very small handheld and laptop sized systems, a single phased array probe port may be provided.

[0004] Therefore, a need exists for an improved interface between the CW Doppler probe and the ultrasound system.

BRIEF DESCRIPTION OF THE INVENTION

[0005] In one embodiment, a stand-alone continuous wave (CW) Doppler probe (CW probe) comprises a scanning end that has a single transmit element and a single receive element. A connector has probe connecting elements configured to interface with port connecting elements of a probe port that is provided on an ultrasound system. The port connecting elements are configured to connect with system channels of the ultrasound system. Transmit circuitry connects a first set of the probe connecting elements in parallel, and the transmit circuitry is interconnected with the transmit element. Receive circuitry connects a second set of the probe connecting elements in parallel, and the receive circuitry is interconnected with the receive element.

[0006] In another embodiment, a stand-alone CW probe comprises a scanning end that has a single transmit element and a single receive element. The CW probe also has a connector that has a plurality of probe connecting elements that are configured to interface with a plurality of port connecting elements of a probe port provided on an ultrasound system. The probe port is configured to accept a connector of a phased array probe. The plurality of port connecting elements is configured to connect with system channels of the ultrasound system.

[0007] In yet another embodiment, a method for powering a stand-alone CW probe using a phased array connector comprises determining respective areas of a single transmit element and a single receive element within a CW probe. N transmit channels are connected in parallel within the CW probe to form a transmit line that is interconnected with the transmit element. N is based at least on the area of the transmit element. M receive channels are connected in parallel within the CW probe to form a receive line that is interconnected with the receive element. M is based at least on a dynamic range associated with processing receive signals from the receive element, and the transmit and receive channels are connected through a probe port on an ultrasound system that is configured to interface with phased array probes.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** is a schematic block diagram of an ultrasound system and a stand-alone continuous wave (CW) Doppler probe (CW probe) formed in accordance with an embodiment of the present invention.

[0009] FIG. **2** illustrates a stand-alone CW probe formed in accordance with an embodiment of the present invention.

[0010] FIG. **3** illustrates a schematic diagram of transmit/receive circuitry used to operate the CW probe in accordance with an embodiment of the present invention.

[0011] FIG. **4** illustrates an exemplary miniaturized ultrasound system that may be connected to the CW probe through a phased array probe port in accordance with an embodiment of the present invention.

[0012] FIG. **5** illustrates a hand carried or pocket-sized ultrasound imaging system that may be connected to the CW probe through a phased array probe port in accordance with an embodiment of the present invention.

[0013] FIG. **6** illustrates a console ultrasound imaging system provided on a movable base that may be connected to the CW probe through a phased array probe port in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0014] The foregoing summary, as well as the following detailed description of certain embodiments of the present invention, will be better understood when read in conjunction with the appended drawings. To the extent that the figures illustrate diagrams of the functional blocks of various embodiments, the functional blocks are not necessarily indicative of the division between hardware circuitry. Thus, for example, one or more of the functional blocks (e.g., processors or memories) may be implemented in a single piece of hardware (e.g., a general purpose signal processor or random access memory, hard disk, or the like). Similarly, the programs may be stand alone programs, may be incorporated as subroutines in an operating system, may be functions in an installed software package, and the like. It should be understood that the various embodiments are not limited to the arrangements and instrumentality shown in the drawings.

[0015] As used herein, an element or step recited in the singular and proceeded with the word “a” or “an” should be understood as not excluding plural of said elements or steps, unless such exclusion is explicitly stated. Furthermore, references to “one embodiment” of the present invention are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features. Moreover, unless explicitly stated to the contrary, embodiments “comprising” or “having” an element or a plurality of elements having a particular property may include additional such elements not having that property.

[0016] FIG. **1** is a schematic block diagram of an ultrasound system **100** and a stand-alone continuous wave (CW) Doppler probe (CW probe) **106**. The CW probe **106** interfaces with the system **100** through a probe port **112** that also interfaces with phased array probes. The CW probe **106** has a transmit element **104** and receive element **105** (e.g. piezoelectric elements), as well as integral transmit/receive circuitry **107** within a connector shell **111**. Previously, the transmit/receive circuitry **107** was installed and provided within the system **100** rather than within the CW probe connector or connector shell **111**, and a dedicated CW probe port (not shown) was required to connect the CW probe **106** to the system **100**. In an alternative embodiment, transmit/receive circuitry **109** may be provided within the system **100** or may be removably connected (e.g. removable adapter) while the CW probe **106** is connected to the phased array probe port **112**.

[0017] A CW beamformer **110** within the system **100** controls transmitters **102** to drive the transmit element **104** to emit pulsed ultrasonic signals into a body. The ultrasonic signals are back-scattered from structures in the body, like blood cells or muscular tissue, to produce echoes that return to receive element **105**. The echoes are received by receivers **108** in the system **100**. Processing architecture **114** comprises a control processing module **116**, a demodulation module **118**, a Doppler processing module **120**, and a scan conversion module **122**. Display architecture **124** comprises a display processing module **126** and a monitor **128**. Input **130** may comprise a keyboard, trackball, microphone, switches, knobs, control keys, and the like.

[0018] The port **112** is connected to the output of the transmitters **102** and the inputs of the receivers **108**. The outputs of the receivers **108** are input to the CW beamformer **110**. The CW beamformer **110** is further connected to the input of transmitters **102**, to the control processing module **116** and the input of the demodulation module **118** in processing architecture **114**. The CW beamformer **110** outputs a sum of individually delayed versions of the input signals to the demodulation module **118**.

[0019] In the processing architecture **114**, the output of the demodulation module **118** is connected to an input of the Doppler processing module **120**. Control processing module **116** interfaces to the Doppler processing module **120** and scan conversion module **122**, to the display processing module **126** in the display architecture **124**, and to the input **130**. An output of the Doppler processing module **120** is connected to an input of scan conversion module **122**. An output of scan conversion module **122** is connected to an input of the display processing module **126** in display architecture **124**, and the output of the display processing module **126** is connected to the input of the monitor **128**. An output of the input **130** is connected to the display processing module **126**.

[0020] To generate a transmitted ultrasound beam, the control processing module **116** sends command data to the CW beamformer **110** that tells the CW beamformer **110** to generate transmit parameters to create a transmit beam. The transmit parameters are sent from the CW beamformer **110** to the transmitters **102**. The transmitters **102** use the transmit parameters to properly encode transmit signals to be sent to the CW probe **106** through the port **112**. The transmit signals are identical with respect to each other. The transmit signals excite the transmit element **104** to emit ultrasound waves. As a result, a transmitted beam of ultrasound energy is formed in a subject when the transmit element **104** is acoustically coupled to the subject by using, for example, ultrasound gel.

[0021] The ultrasound waves are backscattered off of tissue and blood samples within the structure. The backscattered wave arrives at the receive element **105**. The receive element **105** is responsive to the backscattered wave and converts the ultrasound energy from the backscattered wave into a received electrical signal that is routed through the port **112**, which distributes the electrical signal to the different receivers **108**. The receivers **108** may amplify and possibly also digitize the received signals and may provide other functions.

[0022] The received signals are sent to the CW beamformer **110**. The CW beamformer **110** applies the same delay to each of the received signals and sums the delayed received signals, which are then passed to the processing architecture **114**. Demodulation module **118** performs demodulation on the received beam signals to create pairs of I and Q demodulated data values. Demodulation is accomplished by comparing the phase and amplitude of the received beam signals to a reference frequency. The I and Q demodulated data values preserve the phase and amplitude information induced by Doppler shifts in the received signals.

[0023] The demodulated data is transferred to Doppler processing module **120**. The Doppler processing module **120** uses standard techniques such as discrete Fourier transform (DFT) processing to generate a set of spectral Doppler data that may be displayed on the monitor **128**. It should be understood that the processing architecture **114** is configured to process ultrasound data according to a plurality of selectable ultrasound modalities and types of ultrasound probes, such as phased array probes, which may also be connected to the system **100** through the port **112**.

[0024] The generalized ultrasound system **100** of FIG. **1** may be embodied in a small-sized system, such as laptop computer or pocket sized system as well as in a larger cart-based system. FIGS. **4** and **5** are directed towards smaller-sized systems, while FIG. **6** is directed towards relatively larger systems. FIGS. **4-6** are discussed further below.

[0025] FIG. **2** illustrates a stand-alone CW probe **106**. The CW probe **106** has a scanning end **200** that houses the transmitter and receiver elements **104** and **105** as shown in FIG. **1**. The scanning end **200** is connected to probe connector **202** with a cable **204**. Wires within the cable **204** convey signals between the scanning end **200** and the connector **202**. An outer housing or the probe connector shell **111**, which typically comprises one or more pieces, encloses the connector **202**. In one embodiment, the transmit/receive circuitry **107** of FIG. **1** is housed within the connector **202**. In another embodiment, the transmit/receive circuitry **107** may be housed within the scanning end **200** and/or within the cable **204**, or may be separated and located at different areas within the connector shell **111** of the CW probe **106**. For example, transmit portions of the transmit/receive circuitry **107** may be housed within the scanning end **200** while receiver portions of the transmit/receive circuitry **107** are housed within the connector **202**.

[0026] The connector **202** is configured to be attached to the port **112** on the system **100** that also accepts phased array probes. Therefore, the connector **202** has a plurality of probe connecting elements **206**, such as pins, that interconnect with corresponding port connecting elements (not shown), such as holes, within the port **112**. In another embodiment, the probe connecting elements **206** may be holes for receiving pins (the corresponding port connecting elements) of the port **112**.

[0027] FIG. **3** illustrates a schematic diagram of the transmit/receive circuitry **107**. Interconnection within the stand-alone CW probe **106** and the relationship to the port **112** within the system **100** of FIG. **1** is also shown. Portion **220** of the CW probe **106** indicates the transmit element **104** and the receive element **105**. The transmit and receive elements **104** and **105**, as well as other circuitry discussed below, may be connected to a common ground **224**.

[0028] In this example, the system **100** has **64** system channels, each of which corresponds to one of **64** port connecting elements within the port **112**. As used herein, the term system channel refers to the circuitry as well as the electrical signals associated with the system channel. First, second, third through 64^{th} port connecting elements **226**, **228**, **230** through **232** are indicated and correspond to first, second, third through 64^{th} probe connecting elements **234**, **236**, **238** through **240** in the connector **202** of the CW probe **106**. It should be understood that the system **100** may have more or less channels, such as **32** channels, and that the number of port and probe connecting elements may be different based on different system platforms. For example, a system **100** may use a multiplexer (not shown) to increase the number of system channels used for both transmit and receive operations without increasing the number of connecting elements. In one embodiment, the connector **202** may have a smaller number of probe connecting elements **234-240**, corresponding to the number of system channels used by the transmit/receive circuitry **107**.

[0029] As discussed previously, the CW probe **106** has two elements, the transmit and receive elements **104** and **105**, while an array probe has an array of many elements that may be used for transmit, receive, or both. The areas (or sizes) of transmit and receive elements **104** and **105** are much larger than areas of individual elements of the array probe. The larger area or size of the elements changes such properties as electrical impedance, voltage noise level requirements and electrical driving current requirements, and thus the transmit and receive elements **104** and **105** may not be directly connected to single channels of the system **100**, as is done with array probes. For example, if the transmit and receive elements **104** and **105** are **20** times larger than a typical element used in an array probe with the system **100**, the receive side of the CW probe **106** has an electrical impedance that is **20** times lower, resulting in a requirement for the receivers **108** of the system **100** to have a lower voltage noise level of approximately square root of 20 (i.e., sqrt(20)) times the voltage noise level needed for the array probe. The transmit side of the CW probe **106** requires approximately **20** times the current capability of a single system channel of the system **100**.

[0030] In general, a first plurality of system channels are operated as transmit channels and are connected in parallel within a transmit portion of the transmit/receive circuitry **107**. During transmit, the channels within the first plurality of system channels are programmed to provide identical outputs. A second plurality of system channels are operated as receive channels and are connected in parallel within a receive portion of the transmit/receive circuitry **107**. During receive, the CW beamformer **110** applies identical delays to the received signals before summing and outputting the signals.

[0031] Transmit circuitry **242** will be discussed first. In this example, first, second, third and fourth system channels **244**, **246**, **248** and **250** are connected together in parallel. The first through fourth system channels **244-250** are conveyed from the transmitters **102** of the system **100** through separate probe connector elements **234-240**. This configuration increases the current to drive the relatively larger transmit element **104**. Transmit line **252** conveys the signal from the parallel system channels **244-250** of the transmit circuitry **242** to the transmitter element **104**. Optionally, first, second, third and fourth resistors **254**, **256**, **258** and **260** are connected in series with the first through fourth system channels **244-250**, respectively, to provide short circuit protection for the transmitters **102**. The first through fourth resistors **254-260** are positioned upstream of the transmit line **252** and the transmit element **104**. Although the first through fourth resistors **254-260** are shown, other circuit elements may be used to provide short circuit protection. During operation, all of the transmit channels (e.g. first through fourth system channels **244-250**) are programmed to have the same delay. In other words, the transmitters **102** output the same transmit signal on all of the system channels **244-250**.

[0032] By placing the transmit channels in parallel, a higher current capability is obtained and a cleaner transmit waveform having lower noise is achieved because the output voltage (conveyed on transmit line **252**) is the average of four contributions. Therefore, the noise reduces by a factor of sqrt(4), assuming uncorrelated noise between the transmit channels. More or less than four transmit channels may be used, depending upon the current capability and a predetermined voltage noise level (e.g. average voltage noise level) associated with the transmit signal of one transmit channel.

[0033] Receive circuitry **270** will now be discussed. Forty-ninth through sixty-fourth system channels **272** through **274** are connected together in parallel. Receive line **276** conveys the receive signal from the receive element **105** to the 16 parallel system channels **272-274**. Again, during operation, all of the receive channels are programmed to have the same delay (such as in the CW beamformer **110**).

[0034] By placing the receive channels in parallel, the effective voltage noise level is reduced by a factor of the square root of the number of parallel channels, in this example, sqrt(16). Therefore, if the voltage noise level of one receive channel is 1.3 nanovolt/root Hertz (nV/rtHz), the voltage noise level after paralleling is reduced to 1.3/sqrt(16) =0.325 nV/rtHz. By paralleling the receive channels, the combined receive channels may form an input signal to the CW beamformer **110** that has a larger dynamic range compared to a configuration wherein only a single receive channel is used. The dynamic range of the input signal (to the CW beamformer **110**) may be defined as the ratio between the maximum input level and the intrinsic voltage noise level of the received signal over the processing bandwidth.

[0035] Impedance matching circuitry, such as a transformer **278**, is placed in the receive path (interconnected with the receive line **276**) to transform the electrical impedance of the receive element **105** to maximize the dynamic range of the receivers **108** (i.e. the connected load) while achieving a desired or predetermined voltage noise level. Other component(s) may be used to form the impedance matching circuitry. In one embodiment, the transformation ratio, indicated on FIG. **3** as n:1, may be selected so that the transformed thermal noise from the electrical impedance of the receive element **105** is approximately 2 times the equivalent input noise of the receivers **108**.

[0036] An inductor **280** may also be used in the receive path to tune out the capacitance of the parallel system channels **272-274**, such as at a CW Doppler frequency f0 (i.e. the center operating frequency of the CW probe **106**). Assuming that a per-channel input capacitance is Cin and that N channels are connected in parallel, the overall input capacitance is Npar*Cin. Equation 1 may be used to calculate the value of the inductor **280**:

$$Ltune=1/(Npar*Cin*(2*pi*f0)^2) \quad \text{Equation 1}$$

[0037] Optionally, a capacitor may be placed in-line with each receive system channel **272-274**, for example, capacitors **282** and **284** may be placed in-line with the forty-ninth and sixty-fourth system channels **272** and **274**, respectively. The capacitors **282** and **284** are positioned downstream with respect to the receive line **276** and the receive element **105**. The capacitors **282** and **284** may be used to block DC components if necessary, depending upon the design of the receivers **108**. In some embodiments, series capacitance may already be included as a part of the input of the receivers **108**.

[0038] FIG. **4** illustrates an exemplary miniaturized ultrasound system **132** that may be connected to the CW probe **106** through a port **136** that also accepts phased array probes. The transmit/receive circuitry **107** is provided within the CW probe **106** or optionally, may be provided within the system **132** as transmit/receive circuitry **109** (as shown in FIG. **1**). A user interface **140** (that may also include an integrated display **142**) is provided to receive commands from an operator. As used herein, "miniaturized" means that the ultrasound system **132** is a handheld or hand-carried device or is configured to be carried in a person's hand, pocket, briefcase-sized case, or backpack. For example, the ultrasound system **132** may be a hand-carried device having a size of a typical laptop computer, for instance, having dimensions of approximately 2.5 inches in depth, approximately 14 inches in width, and approximately 12 inches in height. The ultrasound system **132** may weigh about ten pounds, and thus is easily portable by the operator. The integrated display **142** (e.g., an internal display) is also provided and is configured to display a medical image.

[0039] The ultrasonic data may be sent to an external device **138** via a wired or wireless network **134** (or direct connection, for example, via a serial or parallel cable or USB port). In some embodiments, external device **138** may be a computer or a workstation having a display. Alternatively, external device **138** may be a separate external display or a printer capable of receiving image data from the hand carried ultrasound system **132** and of displaying or printing images that may have greater resolution than the integrated display **142**.

[0040] FIG. **5** illustrates a hand carried or pocket-sized ultrasound imaging system **176** wherein the display **142** and user interface **140** form a single unit. By way of example, the pocket-sized ultrasound imaging system **176** may be a pocket-sized or hand-sized ultrasound system approximately 2 inches wide, approximately 4 inches in length, and approximately 0.5 inches in depth and weighs less than 3 ounces. A probe port **178** provides connection to scanning devices such as the CW probe **106** as well as phased array or other probes. The display **142** may be, for example, a 320×320 pixel color LCD display (on which a medical image **190** may be displayed). A typewriter-like keyboard **180** of buttons **182** may optionally be included in the user interface **140**.

[0041] Multi-function controls **184** may each be assigned functions in accordance with the mode of system operation. Therefore, each of the multi-function controls **184** may be configured to provide a plurality of different actions. Label display areas **186** associated with the multi-function controls **184** may be included as necessary on the display **142**. The system **176** may also have additional keys and/or controls **188** for special purpose functions, which may include, but are not limited to "freeze," "depth control," "gain control," "color-mode," "print," and "store."

[0042] The smaller sizes of the systems **132** and **176** limits the hardware that may be provided therein, as well as the number of probe ports. Having the transmit/receive circuitry **107** provided within the CW probe **106** allows an operator to connect the CW probe **106** to the phased array probe port. Alternatively, the transmit/receive circuitry **109** may be provided within the system **176**.

[0043] FIG. **6** illustrates a console ultrasound imaging system **145** provided on a movable base **147**. The console ultrasound imaging system **145** may also be referred to as a cart-based system. A display **142** and user interface **140** are provided and it should be understood that the display **142** may be separate or separable from the user interface **140**. The user interface **140** may optionally be a touchscreen, allowing the operator to select options by touching displayed graphics, icons, and the like.

[0044] The user interface **140** also includes control buttons **152** that may be used to control the console ultrasound imaging system **145** as desired or needed, and/or as typically provided. The user interface **140** provides multiple interface options that the user may physically manipulate to interact with ultrasound data and other data that may be displayed, as well as to input information and set and change scanning parameters. The interface options may be used for specific inputs, programmable inputs, contextual inputs, and the like. For example, a keyboard **154** and track ball **156** may be provided.

[0045] The system **145** has at least one probe port **160** for accepting probes. A single port **160** may accept the CW probe **106** as well as phased array probes. The transmit/receive circuitry **107** needed to drive the CW probe **106** may be provided within the CW probe **106**. This provides both a space and cost savings as the CW probe **106** may be used with a plurality of systems rather than being limited to the specific system having the dedicated CW probe port and transmit/receive circuitry installed therein. In another embodiment, the transmit/receive circuitry **109** may be provided within the system **145**, supporting the connection of the CW probe **106** through the phased array probe port **160**.

[0046] A technical effect of at least one embodiment is the ability to interconnect the CW Doppler probe with a phased array probe port on an ultrasound system. This allows the CW probe to be used with systems that do not have a dedicated CW Doppler probe port, as was previously required. The transmit/receive circuitry accomplishes the increased current and improved noise parameters, among other things, needed to operate the CW Doppler probe, and may be included within the CW Doppler probe. This configuration achieves a space and cost savings relative to the ultrasound system and facilitates the use of the CW Doppler probe with smaller-sized systems that may not have room for more than one probe port. Also, no additional transmit/receive circuitry needs to be installed within the ultrasound system. Alternatively, the transmit/receive circuitry may be included within the system, supporting the connection of the CW Doppler probe to the system through the same port that accepts phased array probes.

[0047] It is to be understood that the above description is intended to be illustrative, and not restrictive. For example, the above-described embodiments (and/or aspects thereof) may be used in combination with each other. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from its scope. While the dimensions and types of materials described herein are intended to define the parameters of the invention, they are by no means limiting and are exemplary embodiments. Many other embodiments will be apparent to those of skill in the art upon reviewing the above description. The scope of the invention should, therefore, be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled. In the appended claims, the terms "including" and "in which" are used as the plain-English equivalents of the respective terms "comprising" and "wherein." Moreover, in the following claims, the terms "first," "second," and "third," etc. are used merely as labels, and are not intended to impose numerical requirements on their objects. Further, the limitations of the following claims are not written in means-plus-function format and are not intended to be interpreted based on 35 U.S.C. §112, sixth paragraph, unless and until such claim limitations expressly use the phrase "means for" followed by a statement of function void of further structure.

[0048] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

What is claimed is:

1. A stand-alone continuous wave (CW) Doppler probe (CW probe), comprising:

a scanning end comprising a single transmit element and a single receive element;

a connector having probe connecting elements configured to interface with port connecting elements of a probe port provided on an ultrasound system, the port connecting elements being configured to connect with system channels of the ultrasound system;

transmit circuitry for connecting a first set of the probe connecting elements in parallel, the transmit circuitry being interconnected with the transmit element; and

receive circuitry for connecting a second set of the probe connecting elements in parallel, the receive circuitry being interconnected with the receive element.

2. The CW probe of claim **1**, wherein a number of the probe connecting elements within the first set is based on at least one of a level of current to drive the transmit element and a predetermined voltage noise level associated with one of the system channels.

3. The CW probe of claim **1**, wherein a number of the probe connecting elements within the second set is based on a dynamic range associated with processing a receive signal detected by the receive element.

4. The CW probe of claim **1**, wherein the probe port is configured to accept a connector of a phased array probe.

5. The CW probe of claim **1**, the transmit circuitry further comprising:

a single transmit line connecting the first set of probe connecting elements and the transmit element; and

at least one circuit element configured to be in-line with at least one of the probe connecting elements within the first set of probe connecting elements, the first set of probe connecting elements being connected in parallel downstream of the at least one circuit element.

6. The CW probe of claim **1**, the receive circuitry further comprising:

a single receive line connecting the receive element to the second set of probe connecting elements; and

impedance matching circuitry interconnected with the receive line for changing an impedance of the receive element with respect to a load interconnected with the second set of probe connecting elements through the probe port.

7. The CW probe of claim **1**, the receive circuitry further comprising:

a single receive line connecting the receive element to the second set of probe connecting elements; and

a transformer interconnected with the receive line for changing an impedance of the receive element with respect to a load interconnected with the second set of probe connecting elements through the probe port.

8. The CW probe of claim **1**, the receive circuitry further comprising:

a single receive line connecting the receive element to the second set of probe connecting elements; and

an inductor interconnected with the receive line for tuning out a capacitance associated with the system channels connected to the second set of probe connecting elements.

9. A stand-alone continuous wave (CW) Doppler probe (CW probe), comprising:

a scanning end comprising a single transmit element and a single receive element; and

a connector having a plurality of probe connecting elements configured to interface with a plurality of port connecting elements of a probe port provided on an ultrasound system, the probe port being configured to accept a connector of a phased array probe, the plurality of port connecting elements being configured to connect with system channels of the ultrasound system.

10. The CW probe of claim **9**, further comprising:

a connector shell configured to enclose the connector; and

transmit/receive circuitry being formed within the connector shell of the CW probe, the transmit/receive circuitry connecting first and second sets of the probe connecting elements in parallel, wherein the first set of probe connecting elements is interconnected with the transmit element and the second set of probe connecting elements is interconnected with the receive element.

11. The CW probe of claim **9**, further comprising transmit/receive circuitry for connecting first and second sets of the probe connecting elements in parallel, the first set of probe connecting elements being interconnected with the transmit element and the second set of probe connecting elements being interconnected with the receive element, wherein the transmit/receive circuitry is formed within the connector of the CW probe.

12. The CW probe of claim **9**, further comprising transmit/receive circuitry for connecting first and second sets of the probe connecting elements in parallel, wherein the first set of probe connecting elements is interconnected with the transmit element and the second set of probe connecting elements is interconnected with the receive element, wherein each of the probe connecting elements is interconnected with a separate one of the system channels.

13. The CW probe of claim **9**, further comprising transmit circuitry for connecting a first set of the probe connecting elements in parallel, wherein the first set of probe connecting elements is interconnected with the transmit element, wherein a number of the probe connecting elements within the first set is based on at least one of a level of current associated with the transmit element and a predetermined voltage noise level associated with a transmit signal on one of the system channels.

14. The CW probe of claim **9**, further comprising receive circuitry for connecting a second set of the probe connecting elements in parallel, wherein the second set of probe connecting elements is interconnected with the receive element, wherein a number of the probe connecting elements within the second set is based on a dynamic range associated with processing receive signals detected by the receive element.

15. The CW probe of claim **9**, further comprising transmit/receive circuitry for connecting first and second sets of the probe connecting elements in parallel, wherein the first set of probe connecting elements is interconnected with the transmit element and the second set of probe connecting elements is interconnected with the receive element, wherein the transmit/receive circuitry is formed within the ultrasound system.

16. A method for powering a stand-alone CW Doppler probe (CW probe) using a phased array connector, comprising:

determining respective areas of a single transmit element and a single receive element within a CW probe;

connecting N transmit channels in parallel within the CW probe to form a transmit line that is interconnected with the transmit element, N being based at least on the area of the transmit element; and

connecting M receive channels in parallel within the CW probe to form a receive line that is interconnected with the receive element, M being based at least on a dynamic range associated with processing receive signals from the receive element, the transmit and receive channels being connected through a probe port on an ultrasound system that is configured to interface with phased array probes.

17. The method of claim **16**, wherein N is further based on a current level provided by a single transmit channel.

18. The method of claim **16**, wherein M is further based on an available dynamic range of a single receive channel.

19. The method of claim **16**, wherein the M receive channels are interconnected with a receiver within the ultrasound system through the probe port, the method further comprising transforming an electrical impedance of the receive element based on an input noise level of the receiver.

20. The method of claim **16**, further comprising tuning out a capacitance of the M receive channels with an inductor having a value based on at least an input capacitance of a single receive channel and a center operating frequency of the CW probe.

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专利名称(译)	用于相控阵超声系统的独立CW多普勒探头接口		
公开(公告)号	US20090099453A1	公开(公告)日	2009-04-16
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[标]申请(专利权)人(译)	KRISTOFFERSEN KJELL		
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当前申请(专利权)人(译)	KRISTOFFERSEN KJELL		
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摘要(译)

独立连续波（CW）多普勒探头（CW探头）包括具有单个发射元件和单个接收元件的扫描端。连接器具有探针连接元件，该探针连接元件被配置为与在超声系统上提供的探针端口的端口连接元件接口。端口连接元件被配置为与超声系统的系统通道连接。发送电路并联连接第一组探针连接元件，并且发送电路与发送元件互连。接收电路并联连接第二组探针连接元件，并且接收电路与接收元件互连。