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(54) **IMAGING WITH MULTIPLE APERTURE MEDICAL ULTRASOUND AND SYNCHRONIZATION OF ADD-ON SYSTEMS**

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PCT Pub. Date: **Feb. 11, 2010**

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A61B 8/00 (2006.01)

(52) **U.S. Cl.**
USPC **600/437**; 600/443

(58) **Field of Classification Search**
USPC 600/437–445
See application file for complete search history.

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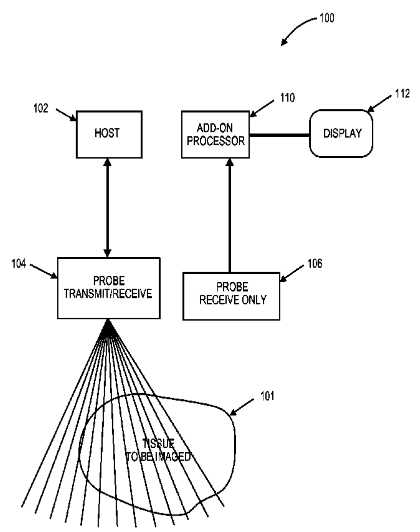
(57) **ABSTRACT**

The benefits of a multi-aperture ultrasound probe can be achieved with add-on devices. Synchronization and correlation of echoes from multiple transducer elements located in different arrays is essential to the successful processing of multiple aperture imaging. The algorithms disclosed here teach methods to successfully process these signals when the transmission source is coming from another ultrasound system and synchronize the add-on system to the other ultrasound system. Two-dimensional images with different noise components can be constructed from the echoes received by individual transducer elements. The disclosed techniques have broad application in medical imaging and are ideally suited to multi-aperture cardiac imaging using two or more intercostal spaces.

26 Claims, 6 Drawing Sheets



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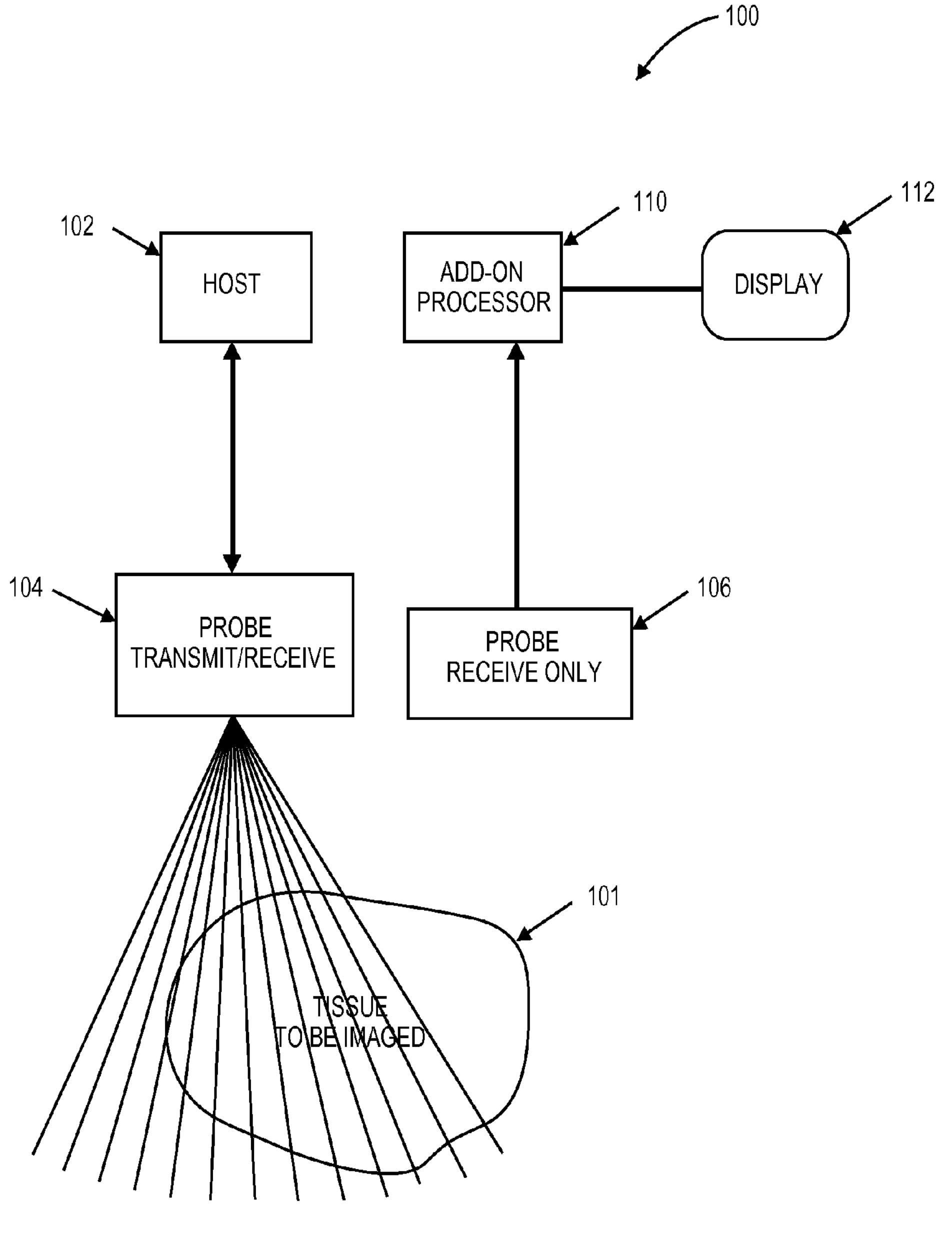

100
102
HOST
110
ADD-ON
PROCESSOR
112
DISPLAY
104
PROBE
TRANSMIT/RECEIVE
106
PROBE
RECEIVE ONLY
101
TISSUE
TO BE IMAGED

FIG. 1A

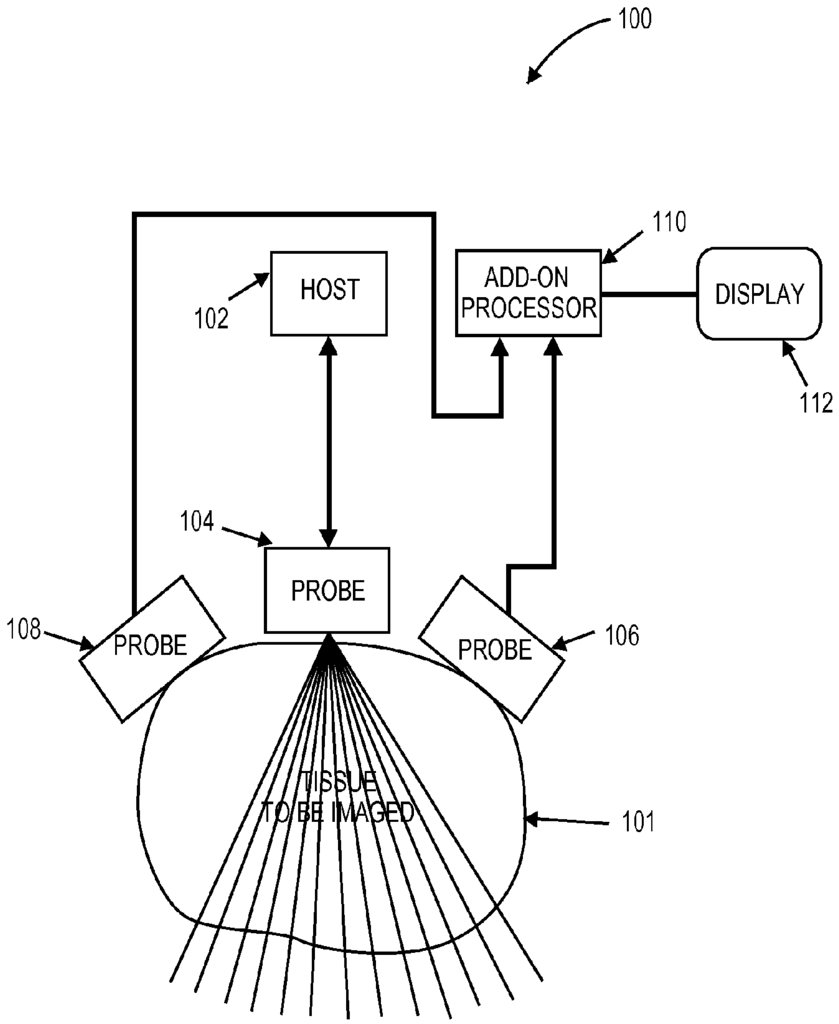

100
110
HOST
ADD-ON
PROCESSOR
DISPLAY
102
112
104
PROBE
108
PROBE
PROBE
106
TISSUE
TO BE IMAGED
101

FIG. 1B

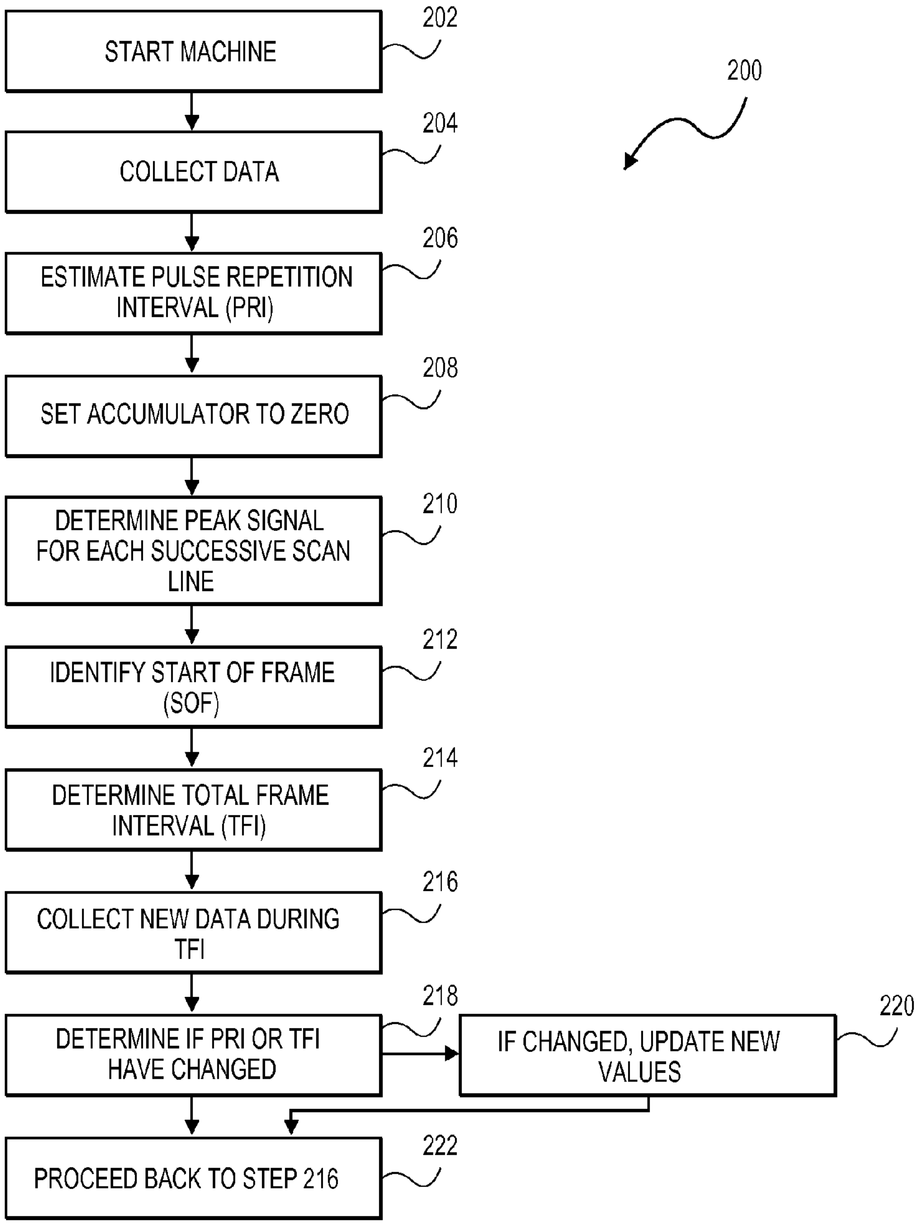
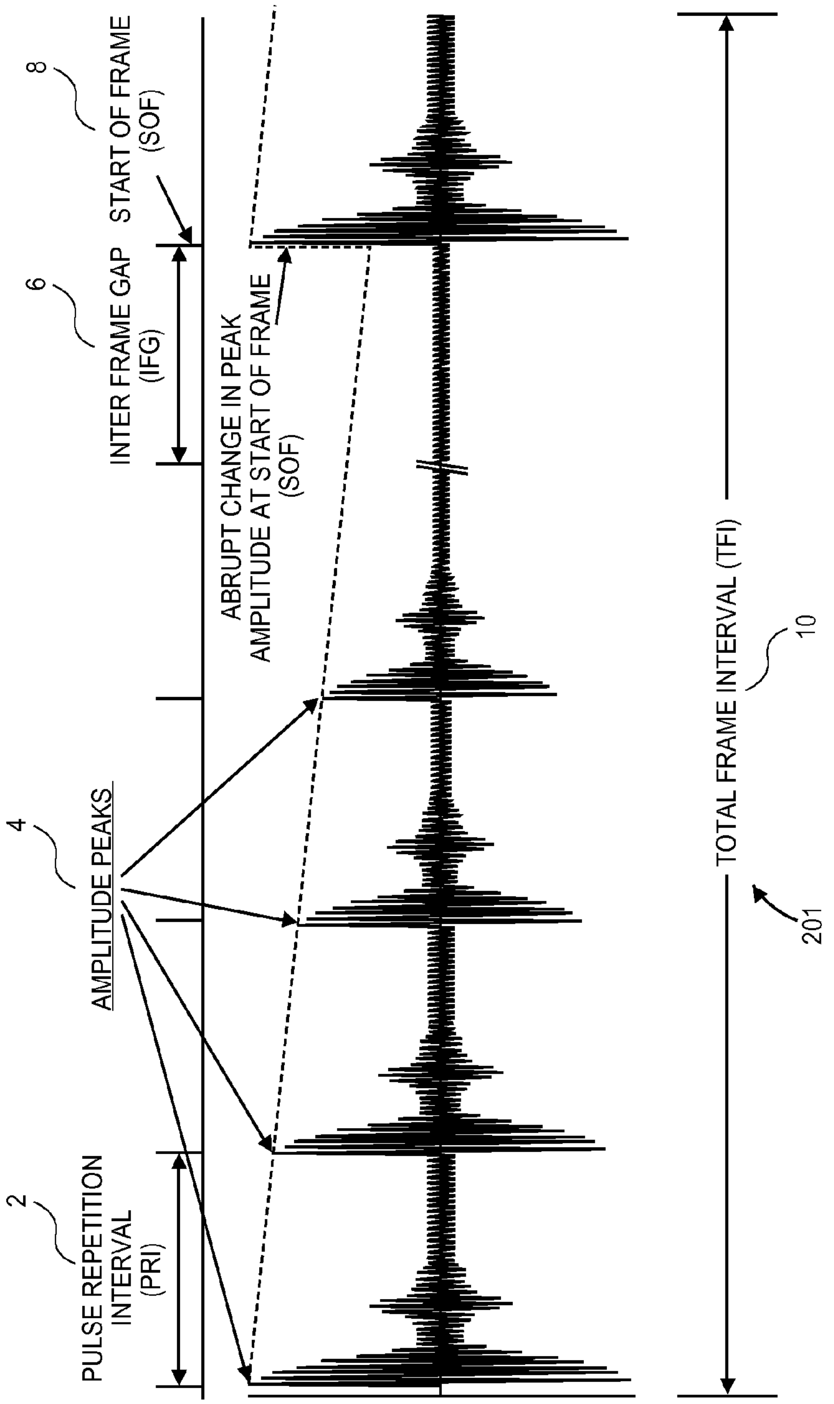

200
START MACHINE
202
COLLECT DATA
204
ESTIMATE PULSE REPETITION INTERVAL (PRI)
206
SET ACCUMULATOR TO ZERO
208
DETERMINE PEAK SIGNAL FOR EACH SUCCESSIVE SCAN LINE
210
IDENTIFY START OF FRAME (SOF)
212
DETERMINE TOTAL FRAME INTERVAL (TFI)
214
COLLECT NEW DATA DURING TFI
216
DETERMINE IF PRI OR TFI HAVE CHANGED
218
IF CHANGED, UPDATE NEW VALUES
220
PROCEED BACK TO STEP 216
222

FIG. 2A



2
PULSE REPETITION INTERVAL (PRI)
4
AMPLITUDE PEAKS
6
INTER FRAME GAP (IFG)
8
START OF FRAME (SOF)
ABRUPT CHANGE IN PEAK AMPLITUDE AT START OF FRAME (SOF)
TOTAL FRAME INTERVAL (TFI)
10
201

FIG. 2B

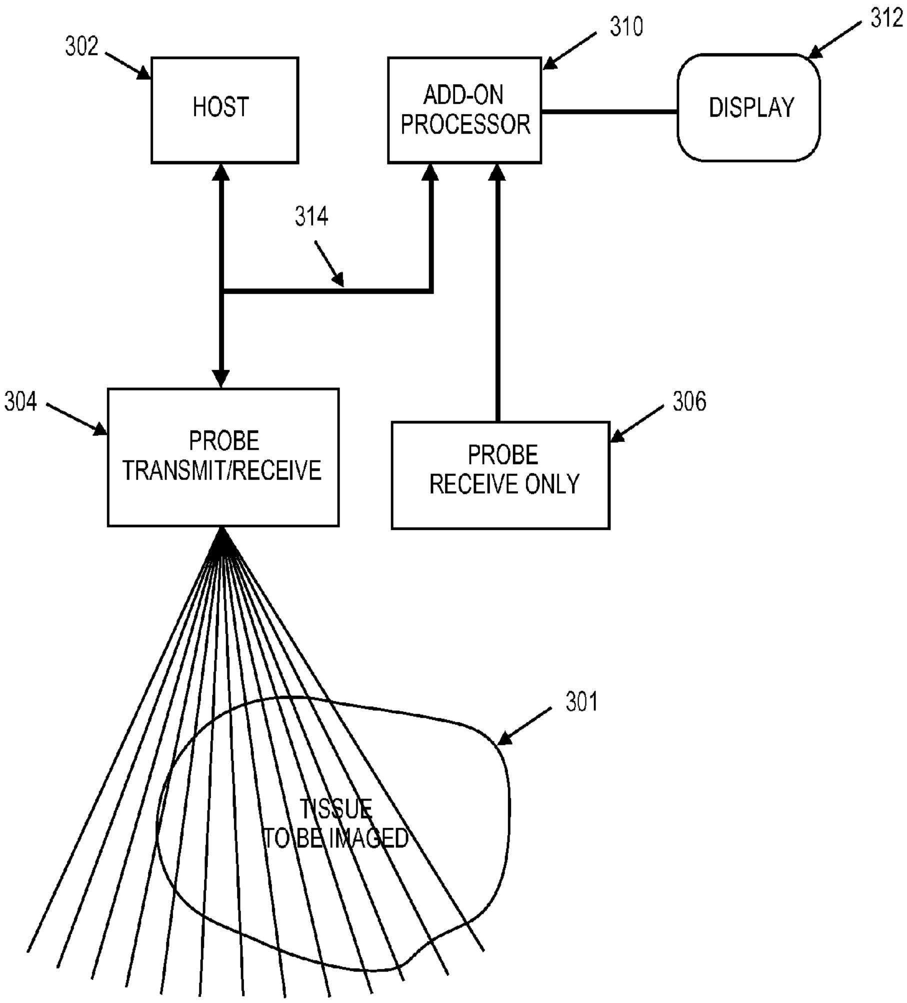

302
HOST
310
ADD-ON
PROCESSOR
312
DISPLAY
314
304
PROBE
TRANSMIT/RECEIVE
306
PROBE
RECEIVE ONLY
301
TISSUE
TO BE IMAGED

FIG. 3A

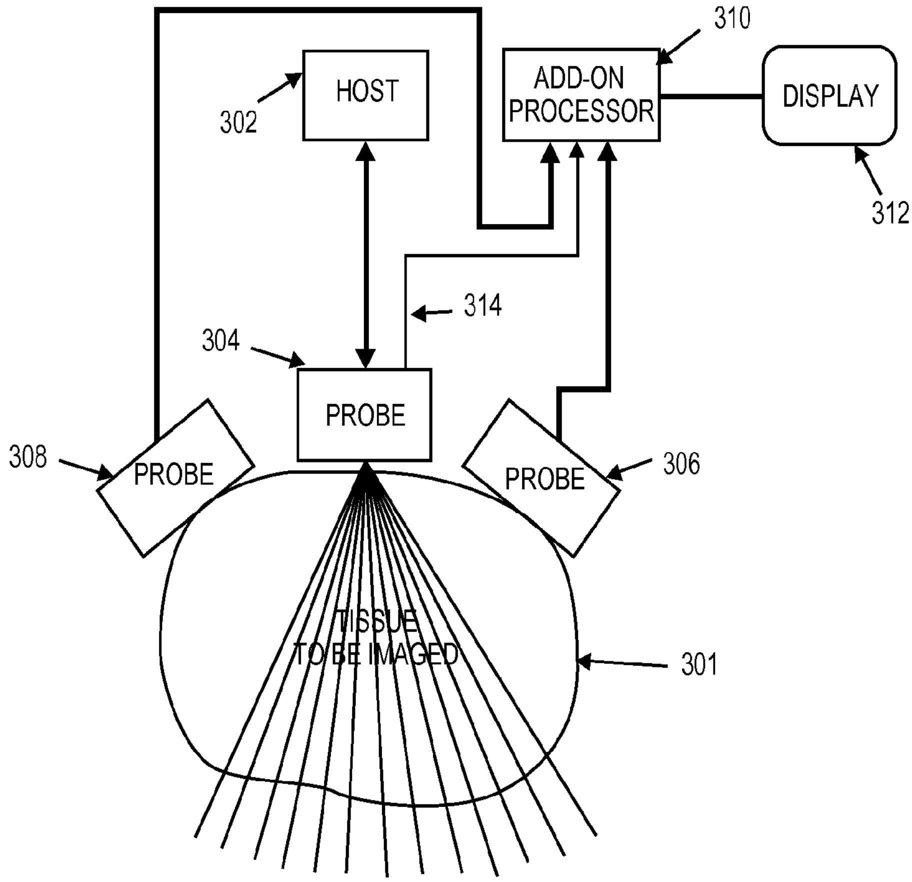

310
ADD-ON PROCESSOR
DISPLAY
HOST
302
312
314
304
PROBE
308
PROBE
PROBE
306
TISSUE TO BE IMAGED
301

FIG. 3B

IMAGING WITH MULTIPLE APERTURE MEDICAL ULTRASOUND AND SYNCHRONIZATION OF ADD-ON SYSTEMS

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit under 35 U.S.C. 119 of U.S. Provisional Patent Application No. 61/087,571, filed Aug. 8, 2008, titled "UNIVERSAL IMAGING AND SYNCHRONIZATION USING MULTIPLE APERTURE APPARATUS IN MEDICAL ULTRASOUND", and U.S. Provisional Patent Application Ser. No. 61/169,264, filed Apr. 14, 2009, titled "METHOD FOR AN ADD-ON MULTIPLE APERTURE PROCESSOR TO DETECT START AND DIRECTION OF PULSE FROM A HOST MACHINE", all which are herein incorporated by reference.

This application is related to U.S. patent application Ser. No. 11/532,013, filed Oct. 11, 2007, titled "METHOD AND APPARATUS TO VISUALIZE THE CORONARY ARTERIES USING ULTRASOUND" which claims priority to U.S. Provisional Patent Application No. 60/765,887, filed Feb. 6, 2006 titled "METHOD AND APPARATUS TO VISUALIZE THE CORONARY ARTERIES USING ULTRASOUND" and U.S. patent application Ser. No. 11/865,501, filed May 1, 2008, titled "METHOD AND APPARATUS TO PRODUCE ULTRASONIC IMAGES USING MULTIPLE APERTURES" which claims priority to U.S. Provisional Patent Application No. 60/862,951 filed Oct. 25, 2006, titled "METHOD AND APPARATUS TO PRODUCE ULTRASONIC IMAGES USING MULTIPLE APERTURES" and U.S. Provisional Patent Application No. 60/940,261, filed May 25, 2007, titled "METHOD AND APPARATUS TO PRODUCE ULTRASONIC IMAGES USING MULTIPLE APERTURES", all which are herein incorporated by reference.

INCORPORATION BY REFERENCE

All publications and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication or patent application was specifically and individually indicated to be incorporated by reference.

FIELD OF THE INVENTION

The present invention relates generally to imaging techniques used in medicine, and more particularly to medical ultrasound, and still more particularly to synchronizing an add-on apparatus to a host ultrasound machine for producing ultrasonic images using multiple apertures.

BACKGROUND OF THE INVENTION

In conventional ultrasonic imaging, a focused beam of ultrasound energy is transmitted into body tissues to be examined and the returned echoes are detected and plotted to form an image. In echocardiography the beam is usually stepped in increments of angle from a center probe position, and the echoes are plotted along lines representing the paths of the transmitted beams. In abdominal ultrasonography the beam is usually stepped laterally, generating parallel beam paths, and the returned echoes are plotted along parallel lines representing these paths. The following description will relate to the angular scanning technique for echocardiography (commonly referred to as a sector scan). However, the same concept with minor modifications can be implemented in abdominal scanners.

The basic principles of conventional ultrasonic imaging are well described in the first chapter of *Echocardiography*, by Harvey Feigenbaum (Lippincott Williams & Wilkins, 5^{th} ed., Philadelphia, 1993). These will not be repeated here except as necessary to illustrate the differences between the conventional techniques and the present invention.

It is well known that the average velocity v of ultrasound in human tissue is about 1540 msec, the range in soft tissue being 1440 to 1670 m/sec (see for example P. N. T. Wells, *Biomedical Ultrasonics*, Academic Press, London, New York, San Francisco, 1977). Therefore, the depth of an impedance discontinuity generating an echo can be estimated as the round-trip time for the echo multiplied by v/2, and the amplitude is plotted at that depth along a line representing the path of the beam. After this has been done for all echoes along all beam paths, an image is formed. The gaps between the scan lines are typically filled in by interpolation.

In order to insonify the body tissues, a beam formed either by a phased array or a shaped transducer is scanned over the tissues to be examined. Traditionally, the same transducer or array is used to detect the returning echoes. This design configuration lies at the heart of one of the most significant limitations in the use of ultrasonic imaging for medical purposes; namely, poor lateral resolution. Theoretically the lateral resolution could be improved by increasing the aperture of the ultrasonic probe, but the practical problems involved with aperture size increase have kept apertures small and lateral resolution poor. Unquestionably, ultrasonic imaging has been very useful even with this limitation, but it could be more effective with better resolution.

In the practice of cardiology, for example, the limitation on single aperture size is dictated by the space between the ribs (the intercostal spaces). For scanners intended for abdominal and other use, the limitation on aperture size is not so obvious, but it is a serious limitation nevertheless. The problem is that it is difficult to keep the elements of a large aperture array in phase because the speed of ultrasound transmission varies with the type of tissue between the probe and the area of interest. According to the book by Wells (cited above), the speed varies up to plus or minus 10% within the soft tissues. When the aperture is kept small, the intervening tissue is, to a first order of approximation, all the same and any variation is ignored. When the size of the aperture is increased to improve the lateral resolution, the additional elements of a phased array may be out of phase and may actually degrade the image rather than improving it.

Instead of replacing the single transmit/receive ultrasound probes that are common in the medical industry, it would be advantageous and cost effective to increase the resolution of these devices with an add-on system. However, adding resolution to existing system would face additional challenges, such as synchronizing an add-on system to the existing host ultrasound machine.

SUMMARY OF THE INVENTION

The present invention relates generally to imaging techniques used in medicine, and more particularly to medical ultrasound, and still more particularly to synchronizing an add-on apparatus to a host ultrasound machine for producing ultrasonic images using multiple apertures.

One aspect of the invention provides an add-on ultrasound system, comprising an ultrasound receiver configured to receive ultrasound pulses transmitted from a host probe, a processor coupled to the ultrasound receiver, the processor comprising an algorithm configured to synchronize the add-on system to the host probe.

In some embodiments, the add-on ultrasound system can further include a display adapted to display ultrasound images from the processor. The display can be a GUI, for example.

In some embodiments, the add-on ultrasound system can include multiple ultrasound receivers, such as two, three, or even more ultrasound receiver.

One aspect of the invention provides an algorithm configured to process the received ultrasound pulses to synchronize the add-on system to the host ultrasound probe. In some embodiments, the algorithm can be adapted to calculate a start of frame of the transmitted ultrasound pulses. The start of frame can be calculated in a variety of ways. In some embodiments, the algorithm can calculate the start of frame by identifying an interval between amplitude peaks that is substantially larger than a pulse repetition interval. In other embodiments, the algorithm can calculate the start of frame by identifying a large change in peak amplitudes during successive scan lines. The large change in peak amplitudes can be from a low to a high or vice versa, for example.

In another aspect of the invention, the add-on ultrasound system can further comprise a tap that couples the host ultrasound probe to the add-on system. Since the tap has access to all the data from the host probe, the processor of the add-on ultrasound system can be adapted to process data from the tap to synchronize the add-on system to the host ultrasound probe.

Another aspect of the invention is a method of synchronizing an add-on ultrasound system to a host ultrasound probe, comprising, transmitting ultrasound pulses from the host ultrasound probe, receiving the ultrasound pulses with the add-on ultrasound system, and synchronizing the add-on ultrasound system to the host ultrasound probe with a processor.

In some embodiments, the receiving step further comprises receiving the ultrasound pulses with a receiving probe of the add-on ultrasound system. In other embodiments, the receiving step further comprises receiving the ultrasound pulses with a plurality of receiving probes of the add-on ultrasound system.

In some aspects of the invention, the synchronizing step further comprises synchronizing the add-on ultrasound system to the host ultrasound probe with the processor based on the transmitted ultrasound pulses. The add-on ultrasound system can be synchronized to the host ultrasound probe with an algorithm in the processor.

In some embodiments, the algorithm can calculate a start of frame of the transmitted pulses. The algorithm can calculate the start of frame by identifying an interval between amplitude peaks that is substantially larger than a pulse repetition interval. In another embodiment, the algorithm can calculate a start of frame by identifying a large change in peak amplitudes during successive scan lines. The peak amplitude changes can be from a low to a high or vice versa, for example.

In some embodiments, the synchronizing step can further comprise synchronizing the add-on ultrasound system to the host ultrasound probe with the processor adapted to process data from a tap that couples the host ultrasound probe to the add-on system.

Another aspect of the invention is providing ultrasound images to a display from the add-on ultrasound system. The ultrasound pulses can transmitted into tissue and the ultrasound images can be of the tissue.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features of the invention are set forth with particularity in the claims that follow. A better understanding of the features and advantages of the present invention will be obtained by reference to the following detailed description that sets forth illustrative embodiments, in which the principles of the invention are utilized, and the accompanying drawings of which.

In the drawings:

FIGS. **1A-1B** illustrate add-on systems with single or multiple receive probes to be used with a host ultrasound machine for providing high-resolution ultrasound images.

FIG. **2A** is a flowchart showing one embodiment of a sequence of operations that an algorithm in an add-on system may use to synchronize the add-on system to a host ultrasound machine.

FIG. **2B** is a plot illustrating the data collected by an add-on ultrasound system.

FIGS. **3A-3B** illustrate add-on systems with single or multiple receive probes and high impedance taps to be used with a host ultrasound machine for providing high-resolution ultrasound images.

DETAILED DESCRIPTION OF THE INVENTION

Various embodiments of an ultrasound imaging system are described.

Returned echoes in ultrasonography can be detected by a separate relatively non-directional receiving probe located away from the insonifying probe (e.g., the transmitting probe), and the non-directional receive transducer can be placed in a different acoustic window from the insonifying probe. This non-directional receiving probe can be called an omni-directional or receiving probe because it can be designed to be sensitive to a wide field of view.

If the echoes detected at the receiving probe are stored separately for every pulse from the insonifying transducer, the entire two-dimensional image can be formed from the information received by a single receiving probe. Additional copies of the image can be formed by additional omni-directional probes collecting data from the same set of insonifying pulses.

In one embodiment, an add-on device can be designed as a receive-only device while using an existing ultrasound machine from another manufacturer to act as the insonifying probe and transmit the ultrasound. A design of this type would allow the diagnostic laboratory or medical office to upgrade the B-mode, M-mode, or Doppler resolution of an existing machine without replacing it.

FIGS. **1A** and **1B** illustrate an external add-on system **100** for use with a host ultrasound system **102** and host transmit/receive probe **104** to image tissue **101**. In FIG. **1A**, the add-on system **100** includes a single receiving probe **106**, and in FIG. **1B**, the add-on system includes two receiving probes **106** and **108**. The receiving probes **106** and **108** can have receive only capabilities, for example. In other embodiments, the receiving probes **106** and **108** can have transmit and receive capabilities. In other embodiments, the add-on system can include any number of receiving probes, such as three or more receiving probes. As shown in FIGS. **1A-1B**, the add-on system **100** can further include add-on processor **110** and display **112**. Display **112** can be a graphical user interface (GUI), or other appropriate display. Provision is made for time-gain-controls, overall gain, post-processing curves by means of soft buttons, compression levels, and depth of display. Other controls can conveniently be added to the display.

Synchronization of the receiving probes with the host probe is essential for the add-on system described herein. Without synchronizing the receiving probes to the host probe, the add-on system has no way of using the transmitted pulses from the host probe. Methods and algorithms for synchronizing the add-on system **100** to the host system **102** and host probe **104** can be implemented in add-on processor **110**, which will be discussed below.

For the ultrasound systems described herein, the transmit functions can be handled by the host ultrasound system and host transmit/receive probe (e.g., a standard ultrasound machine), whereas the receive and display functions can be performed by the add-on system. In order for the add-on system to work with a majority of other manufacturer's current and future ultrasound devices (hereinafter to be referred to as the host system and host probe), it is necessary for the add-on system to deduce most of the properties of the host machine from the host machine or from the received ultrasound signals alone.

The first and most likely strongest pulses of ultrasound received will be directly from the transmit probe. These can easily be distinguished from echoes from deep tissues because they are first and strongest. From these received signals, the pulse repetition interval (PRI), the end of frame gap time, if any, the Total Frame Interval (TFI), and the maximum depth of penetration can be measured. The PRI, which corresponds to a time interval during which a scan line of echo data is collected, is defined as the elapsed time from the beginning of one pulse to the start of the next pulse. The maximum depth of penetration can be determined from the PRI and the known speed of sound in tissue. The actual depth of interest can be selected by a user of the system or can be a default percentage of the maximum depth of penetration.

An essential but more difficult parameter to estimate is the start time of the transmit pulse. Triggering on the first received pulse would be too noisy and would cause objectionable jitter from line to line resulting in degradation of the image. Assuming only that the PRI is a constant for a given set of settings on the host system, the estimated start time for the n'th line is simply the start time for the first line+(n−1)*(pulse repetition interval). It remains to estimate the start of the first line of a sector scan.

In FIGS. **1A-1B**, the timing of the start of the transmit pulse from the host system and host probe can be deduced from the ultrasound pulses transmitted by the host probe and received by one of the receiving probes on either side of the host probe. The first detection of the transmit pulse will be delayed from the start of the transmit pulse because of the distance the transmit pulse has to travel to get to the receiving probe. However, that time delay can be calculated from the probe geometry and subtracted from the time that the pulse is first detected.

The main requirement for the measurement of the start of the transmit pulse is that the PRI be constant for a given set of settings and that a "flywheel" algorithm be used to estimate start of line in fixed repetition intervals. Because PRI is changed only infrequently, the estimation of PRI can be adapted over many scan cycles.

One embodiment of a method of synchronizing an add-on ultrasound system to a host ultrasound probe will now be described. Referring to add-on system **100** of FIGS. **1A-1B**, host ultrasound probe **104** can transmit ultrasound pulses into tissue **101**. The transmitted pulses can be received by the add-on system, such as by receiving probe **106**. In some embodiments, such as in FIG. **1B**, the add-on system can include a plurality of receiving probes for receiving the transmitted ultrasound signals (e.g., receiving probes **106** and **108**). Add-on processor **110** can then synchronize the add-on system to the host ultrasound probe. The processor can use an algorithm or algorithms to synchronize the add-on system to the host probe. When the add-on system is synchronized to the host ultrasound probe, the add-on system can provide high-resolution images of the target tissue being imaged to a display, such as to a GUI.

FIG. **2A** shows a flowchart **200** illustrating one embodiment of a flywheel algorithm for determining the timing of the start of a transmit pulse from a host system. FIG. **2B** shows a plot **201** illustrating a collection of data collected and used by the algorithm to synchronize an add-on system to a host machine. In FIG. **2B**, the data collected can include PRI **2**, Amplitude Peaks **4**, IFG **6**, SOF **8**, and TFI **10**. It should be understood that the algorithms described herein typically are executed by the add-on processor **110** described above. These algorithms can be programmed into the add-on processor as firmware, software, or hardware, or a combination of all three.

At step **202** of flowchart **200**, the add-on system is started (i.e., powered or booted up).

At step **204**, the add-on system begins to collect intervals of data. The data can be collected from the host probe, for example, or in some embodiments, from taps to the host probe. The data can be collected for several seconds, such as for approximately 1 to 2 seconds. The data collected will include intervals between peak amplitudes. The interval from one peak amplitude to the next peak amplitude occurrence corresponds to the PRI (see, for example, PRI **2** of FIG. **2B**).

Next, at step **206** of flowchart **200**, the PRI is estimated. As described above, the PRI is the elapsed time from the beginning of one pulse to the start of the next pulse. The PRI can be calculated by the add-on processor of the add-on system to be the median of the set of intervals collected during step **204**.

Next, at step **208**, the number of samples or pulses is counted by an accumulator function of the add-on processor. The accumulator function should be initialized to a value of zero before counting the number of sample times. The accumulator function is a counter of sample times which counts time for a total frame.

Next, at step **210**, the algorithm in the add-on processor continues to collect intervals of data and determines a peak signal (see, for example, Amplitude Peaks **4** in FIG. **2B**) for each successive set of scan line data.

At step **212**, identify Start of Frame (SOF) by one of two methods. In the first embodiment, SOF occurs when the interval between amplitude peaks is substantially larger than the current PRI. This period is designated as the Inter Frame Gap (IFG). If the IFG cannot be distinguished from the PRI, then a second embodiment must be utilized to identify SOF. (see, for example, IFG **6** and PRI **2** in FIG. **2B**).

In the second embodiment, the peak amplitude of successive lines are compared. As the host transmit angle sweeps across the frame, a small change in peak amplitude from line to line occurs. When the transmit angle shifts from the end-of-frame to the beginning-of-frame, there is a corresponding large change in peak amplitude. This change is used to identify SOF. See, for example, how the Amplitude Peaks **4** in FIG. **2B** slowly change from line to line until a large change at SOF **8**. The peak amplitudes can change from a low to a high, as shown in FIG. **2B**, or vice versa.

At step **214**, the add-on processor determines the total frame interval. The total frame interval is the interval between successive SOF times (in samples). See, for example, TOF **10** in FIG. **2**B.

At step **216**, the add-on system collects another set of data from.

At step **218**, the algorithm in the add-on processor can determine if the PRI or TFI has changed. If changes are identified, the add-on system can update the new PRI and TFI values in **220**.

At step **222**, the add-on processor proceeds again to step **216** and continues to collect new data. The add-on processor continues to evaluate data at step **218** and updates the PRI and TFI if changes are identified.

FIGS. **3**A-**3**B illustrate another embodiment of an external add-on system **300** for use with a host ultrasound system **302** and host transmit/receive probe **304** to image tissue **301**, the system further including high impedance taps **314** to connect the add-on system to the host system and probe. The taps **314** can be wires, for example. In FIGS. **3**A-**3**B, host ultrasound system **302**, host transmit/receive probe **304**, receiving probes **306** and **308**, add-on processor **310**, and display **312** can correspond, respectively, to host ultrasound system **102**, host transmit/receive probe **104**, receiving probes **106** and **108**, add-on processor **110**, and display **112** of FIGS. **1**A-**1**B. The taps **314** can connect from host probe **304** to add-on processor **310** to detect the start time and direction of the pulses transmitted from the host probe. In this configuration, all of the transmit pulses can be available to the add-on processor via the taps, instead of needing an algorithm to synchronize the add-on system to the host system as described above with reference to FIGS. **1**A-**1**B and FIG. **2**.

The taps **314** can wire into the transmit/receive probe of the host machine in order to detect directly the start of the transmit pulse. Also, by using this method, the direction of each transmitted pulse can be determined by monitoring the start pulse on a subset of two or more elements of the transmit array. In most current sector scan machines, the direction of the transmit beams progresses monotonically from one side of the sector to the other. In some advanced host machines, the beams may not be sent out in equal increments of angle from one pulse to the next, but instead may be transmitted in some interlaced order. When working with such a machine, it would be necessary to calculate the direction of each transmit pulse.

Another embodiment of a method of synchronizing an add-on ultrasound system to a host ultrasound probe will now be described. Referring to add-on system **300** of FIGS. **3**A-**3**B, host ultrasound probe **304** can transmit ultrasound pulses into tissue **301**. The transmitted pulses can be received by the add-on system, such as by receiving probe **306**. In some embodiments, such as in FIG. **3**B, the add-on system can include a plurality of receiving probes for receiving the transmitted ultrasound signals (e.g., receiving probes **306** and **308**). Add-on processor **310** can then synchronize the add-on system to the host ultrasound probe using data from tap **314** that couples the host ultrasound probe to the add-on system. When the add-on system is synchronized to the host ultrasound probe, the add-on system can provide high-resolution images of the target tissue being imaged to a display, such as to a GUI.

As for additional details pertinent to the present invention, materials and manufacturing techniques may be employed as within the level of those with skill in the relevant art. The same may hold true with respect to method-based aspects of the invention in terms of additional acts commonly or logically employed. Also, it is contemplated that any optional feature of the inventive variations described may be set forth and claimed independently, or in combination with any one or more of the features described herein. Likewise, reference to a singular item, includes the possibility that there are plural of the same items present. More specifically, as used herein and in the appended claims, the singular forms "a," "and," "said," and "the" include plural referents unless the context clearly dictates otherwise. It is further noted that the claims may be drafted to exclude any optional element. As such, this statement is intended to serve as antecedent basis for use of such exclusive terminology as "solely," "only" and the like in connection with the recitation of claim elements, or use of a "negative" limitation. Unless defined otherwise herein, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. The breadth of the present invention is not to be limited by the subject specification, but rather only by the plain meaning of the claim terms employed.

What is claimed is:

1. A method of synchronizing an add-on ultrasound system to a host ultrasound probe, comprising:

transmitting ultrasound pulses from the host ultrasound probe;

receiving the ultrasound pulses with an add-on ultrasound receiver of the add-on ultrasound system, the add-on ultrasound system comprising an add-on ultrasound processor; and

synchronizing the add-on ultrasound system to the host ultrasound probe with an algorithm in the add-on ultrasound processor, wherein the algorithm calculates a start of frame of the transmitted ultrasound pulses by identifying a large change in peak amplitudes during successive scan lines.

2. The method of claim **1** wherein the receiving step further comprises receiving the ultrasound pulses with a receiving probe of the add-on ultrasound system.

3. The method of claim **1** wherein the receiving step further comprises receiving the ultrasound pulses with a plurality of receiving probes of the add-on ultrasound system.

4. The method of claim **1** wherein the synchronizing step further comprises synchronizing the add-on ultrasound system to the host ultrasound probe with the add-on ultrasound processor based on the received ultrasound pulses alone.

5. The method of claim **1** wherein the synchronizing step further comprises synchronizing the add-on ultrasound system to the host ultrasound probe with the add-on ultrasound processor adapted to process data from a tap that couples the host ultrasound probe to the add-on system.

6. The method of claim **1** further comprising providing ultrasound images to a display from the add-on ultrasound system.

7. The method of claim **1** wherein the transmitting step further comprises transmitting the ultrasound pulses into tissue.

8. A method of synchronizing an add-on ultrasound system to a host ultrasound probe, comprising:

transmitting ultrasound pulses from the host ultrasound probe;

receiving the ultrasound pulses with an add-on ultrasound receiver of the add-on ultrasound system, the add-on ultrasound system comprising an add-on ultrasound processor; and

synchronizing the add-on ultrasound system to the host ultrasound probe with an algorithm in the add-on ultrasound processor, wherein the algorithm calculates a start of frame of the transmitted ultrasound pulses by identifying when a peak amplitude changes from a low to a high or vice versa.

9. The method of claim **8** wherein the receiving step further comprises receiving the ultrasound pulses with a receiving probe of the add-on ultrasound system.

10. The method of claim **8** wherein the receiving step further comprises receiving the ultrasound pulses with a plurality of receiving probes of the add-on ultrasound system.

11. The method of claim **8** wherein the synchronizing step further comprises synchronizing the add-on ultrasound system to the host ultrasound probe with the add-on ultrasound processor based on the received ultrasound pulses alone.

12. The method of claim **8** wherein the synchronizing step further comprises synchronizing the add-on ultrasound system to the host ultrasound probe with the add-on ultrasound processor adapted to process data from a tap that couples the host ultrasound probe to the add-on system.

13. The method of claim **8** further comprising providing ultrasound images to a display from the add-on ultrasound system.

14. The method of claim **8** wherein the transmitting step further comprises transmitting the ultrasound pulses into tissue.

15. An add-on ultrasound system, comprising:

an add-on ultrasound receiver configured to receive ultrasound pulses transmitted from a host probe;

an add-on processor coupled to the add-on ultrasound receiver, the add-on processor comprising an algorithm configured to synchronize the add-on system to the host probe, wherein the algorithm is adapted to calculate a start of frame of the transmitted ultrasound pulses by identifying a large change in peak amplitudes during successive scan lines.

16. The add-on ultrasound system of claim **15** further comprising a display adapted to display ultrasound images from the add-on processor.

17. The add-on ultrasound system of claim **15** further comprising a second add-on ultrasound receiver.

18. The add-on ultrasound system of claim **15** wherein the algorithm is configured to synchronize the add-on system to the host ultrasound probe based on the received ultrasound pulses alone.

19. The add-on ultrasound system of claim **15** further comprising a tap coupling the host ultrasound probe to the add-on system.

20. The add-on ultrasound system of claim **19** wherein the add-on processor is adapted to process data from the tap to synchronize the add-on system to the host ultrasound probe.

21. An add-on ultrasound system, comprising:

an add-on ultrasound receiver configured to receive ultrasound pulses transmitted from a host probe;

an add-on processor coupled to the add-on ultrasound receiver, the add-on processor comprising an algorithm configured to synchronize the add-on system to the host probe, wherein the algorithm is adapted to calculate a start of frame of the transmitted ultrasound pulses by identifying when a peak amplitude changes from a low to a high or vice versa.

22. The add-on ultrasound system of claim **21** further comprising a display adapted to display ultrasound images from the add-on processor.

23. The add-on ultrasound system of claim **21** further comprising a second add-on ultrasound receiver.

24. The add-on ultrasound system of claim **21** wherein the algorithm is configured to synchronize the add-on system to the host ultrasound probe based on the received ultrasound pulses alone.

25. The add-on ultrasound system of claim **21** further comprising a tap coupling the host ultrasound probe to the add-on system.

26. The add-on ultrasound system of claim **25** wherein the add-on processor is adapted to process data from the tap to synchronize the add-on system to the host ultrasound probe.

* * * * *

专利名称(译)	使用多孔径医疗超声成像和附加系统同步		
公开(公告)号	US8602993	公开(公告)日	2013-12-10
申请号	US13/002778	申请日	2009-08-07
[标]申请(专利权)人(译)	茂伊成像股份有限公司		
申请(专利权)人(译)	MAUI IMAGING , INC.		
当前申请(专利权)人(译)	MAUI IMAGING , INC.		
[标]发明人	SPECHT DONALD F BREWER KENNETH D		
发明人	SPECHT, DONALD F. BREWER, KENNETH D.		
IPC分类号	A61B8/00		
CPC分类号	A61B8/4281 A61B8/4477 A61B8/5207 A61B8/54 G01S7/52046 G01S7/52087 G01S15/8913 G01S15/8927 G01S15/8929 G01S15/8997 A61B8/00		
优先权	61/087571 2008-08-08 US 61/169264 2009-04-14 US		
其他公开文献	US20110178400A1		
外部链接	Espacenet USPTO		

摘要(译)

使用附加设备可以实现多孔径超声探头的优势。来自位于不同阵列中的多个换能器元件的回波的同步和相关对于多孔径成像的成功处理是必不可少的。这里公开的算法教导了当传输源来自另一个超声系统并使附加系统与另一个超声系统同步时成功处理这些信号的方法。具有不同噪声分量的二维图像可以由各个换能器元件接收的回波构成。所公开的技术在医学成像中具有广泛的应用，并且理想地适合于使用两个或更多个肋间空间的多孔径心脏成像。