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Brock-Fisher

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(54) SYSTEM AND METHOD FOR INTERFACING AN ULTRASOUND TRANSDUCER WITH A COMPUTING DEVICE PERFORMING BEAMFORMING PROCESSING

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(52) **U.S. Cl.** **600/443**
(58) **Field of Search** 600/437, 443, 600/447; 128/916

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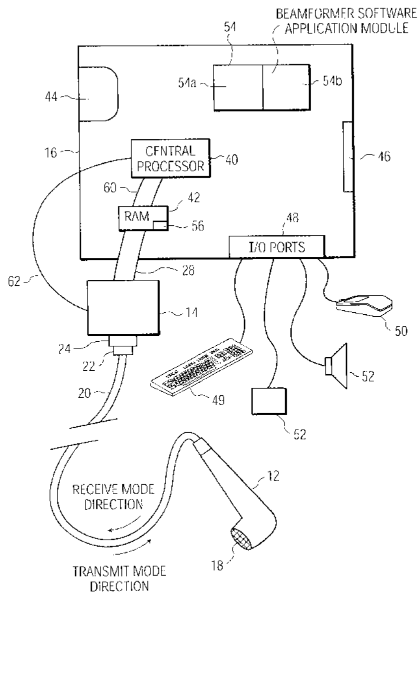
(57) **ABSTRACT**

A beamformer for an ultrasound imaging system is provided, the ultrasound imaging system having a probe having a transducer array for transmitting and receiving analog signals, and a personal computer. The beamformer includes a beamformer software application module configured for execution by the computing device for performing at least partial beamforming processing on digital data transmitted between the transducer array and the computing device, and means for exchanging signals and data between the transducer array and the computing device and performing at least one of A/D and D/A conversions on the exchanged signals and data. In the preferred embodiment, the beamformer further includes a module integrated within architecture of the computing device, wherein the integrated module is preferably Random Access Memory (RAM) included in storage means of the computing device. A method is further provided for performing a transmit beamforming process in an ultrasound system having a computing device and a probe including a transducer array, the method including the steps of performing transmit beamforming processing in the computing device in accordance with transmit settings to generate digital transmit data, storing the digital transmit in the data storage memory, retrieving the digital transmit data from the storage memory, converting the digital transmit data to analog transmit signals, and transmitting the analog transmit signals to the transducer array. A method is further provided for performing a receive beamforming process in an ultrasound system having a computing device including storage memory, an interface module and a probe including a transducer array, the method including the steps of receiving analog signals from the transducer array, converting the analog signals to digital data, storing the digital data in the storage memory, retrieving the digital data from the storage memory, and performing receive beamforming operations on the digital data by the computing device.

20 Claims, 4 Drawing Sheets



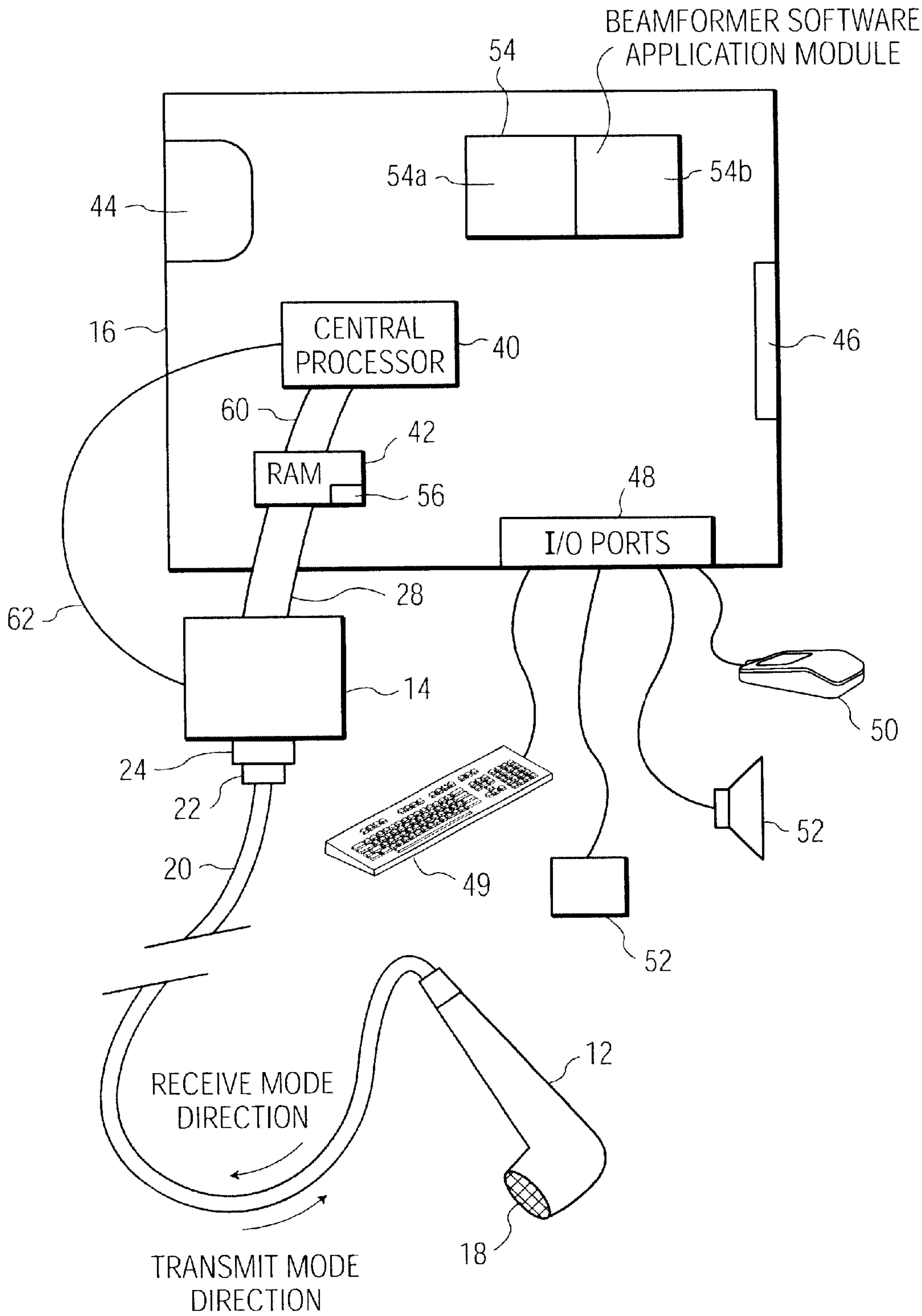

BEAMFORMER SOFTWARE APPLICATION MODULE
54
54a
54b
44
16
CENTRAL PROCESSOR
40
46
60
42
RAM
56
48
I/O PORTS
28
62
14
24
22
50
52
20
49
52
12
RECEIVE MODE DIRECTION
18
TRANSMIT MODE DIRECTION

FIG. 1

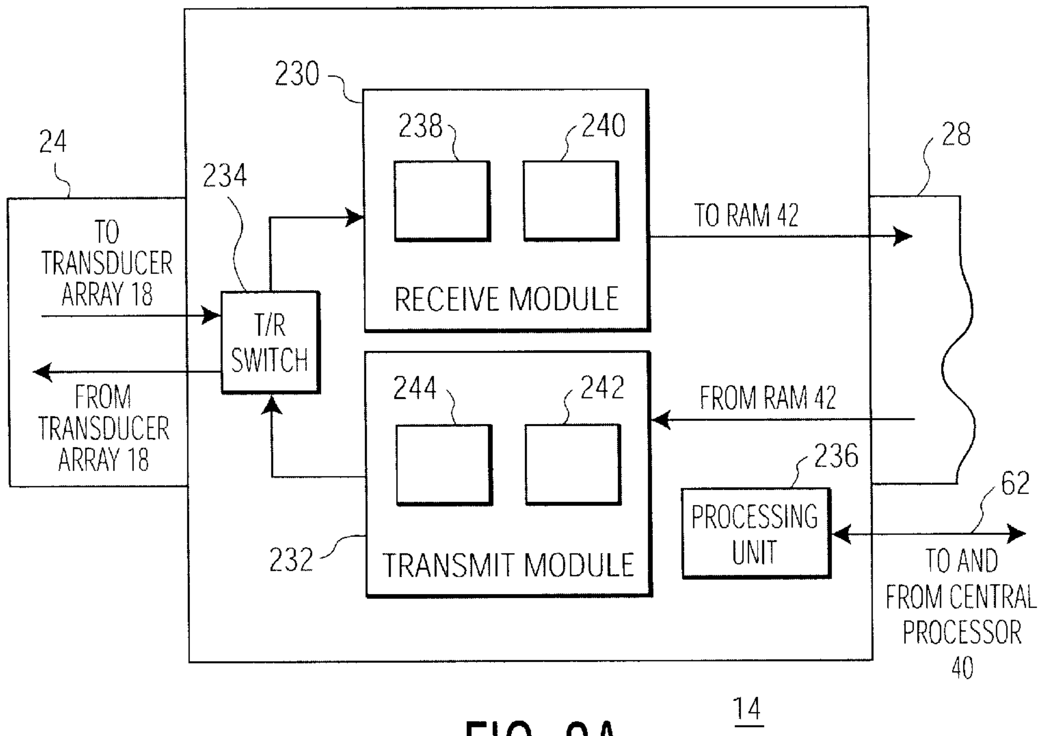

230
238
240
24
234
28
TO RAM 42
TO TRANSDUCER ARRAY 18
RECEIVE MODULE
T/R SWITCH
FROM TRANSDUCER ARRAY 18
244
242
FROM RAM 42
236
62
PROCESSING UNIT
232
TRANSMIT MODULE
TO AND FROM CENTRAL PROCESSOR 40
14

FIG. 2A

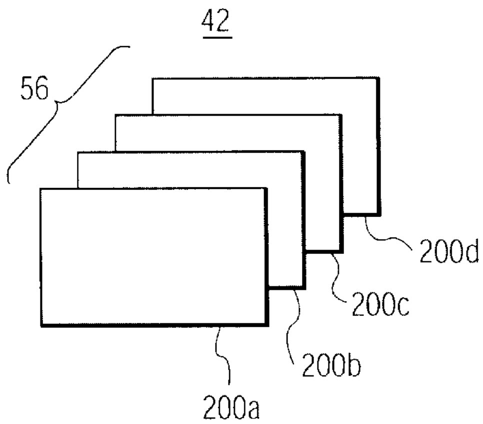

42
56
200d
200c
200b
200a

FIG. 2B

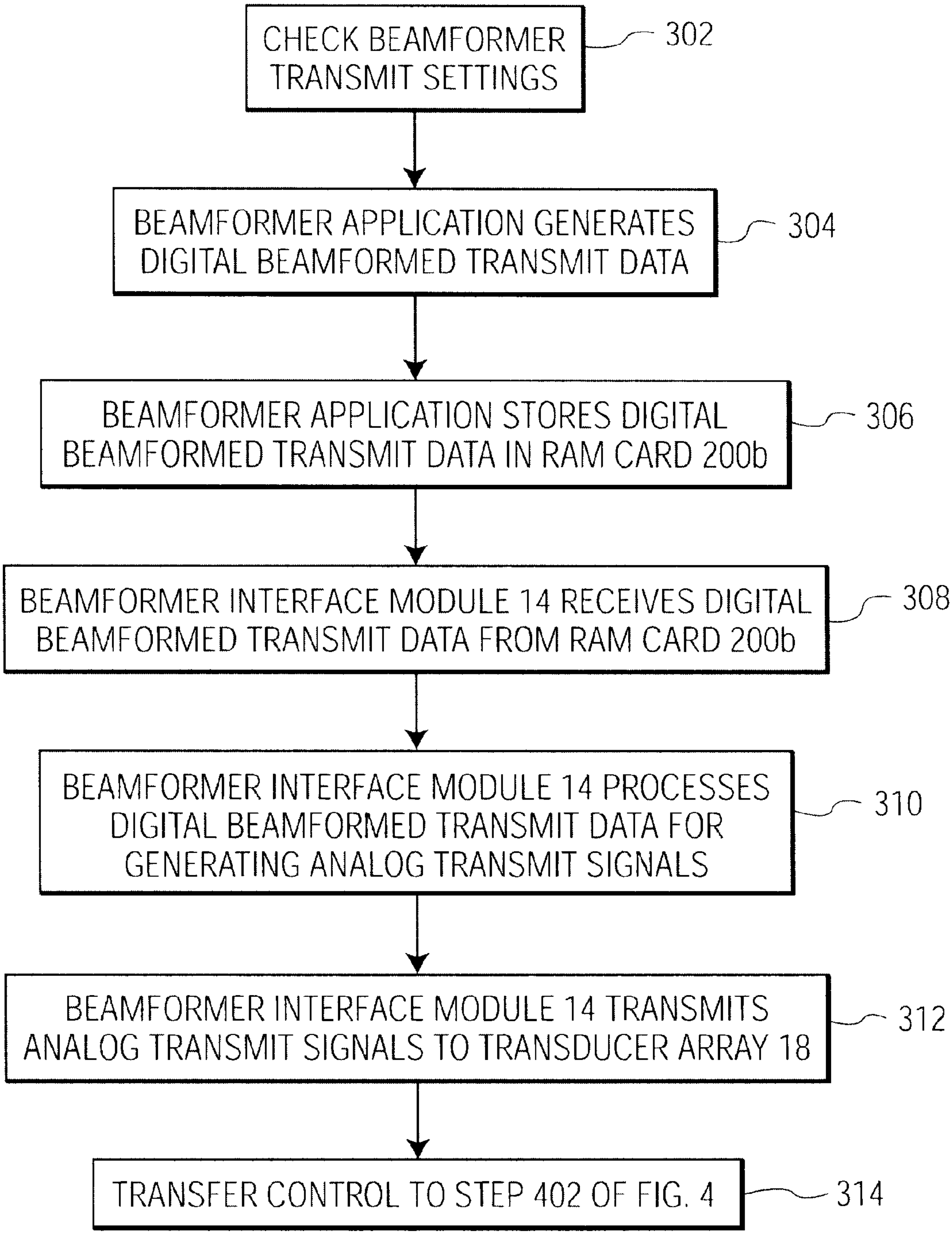

CHECK BEAMFORMER TRANSMIT SETTINGS
302
BEAMFORMER APPLICATION GENERATES DIGITAL BEAMFORMED TRANSMIT DATA
304
BEAMFORMER APPLICATION STORES DIGITAL BEAMFORMED TRANSMIT DATA IN RAM CARD 200b
306
BEAMFORMER INTERFACE MODULE 14 RECEIVES DIGITAL BEAMFORMED TRANSMIT DATA FROM RAM CARD 200b
308
BEAMFORMER INTERFACE MODULE 14 PROCESSES DIGITAL BEAMFORMED TRANSMIT DATA FOR GENERATING ANALOG TRANSMIT SIGNALS
310
BEAMFORMER INTERFACE MODULE 14 TRANSMITS ANALOG TRANSMIT SIGNALS TO TRANSDUCER ARRAY 18
312
TRANSFER CONTROL TO STEP 402 OF FIG. 4
314

FIG. 3

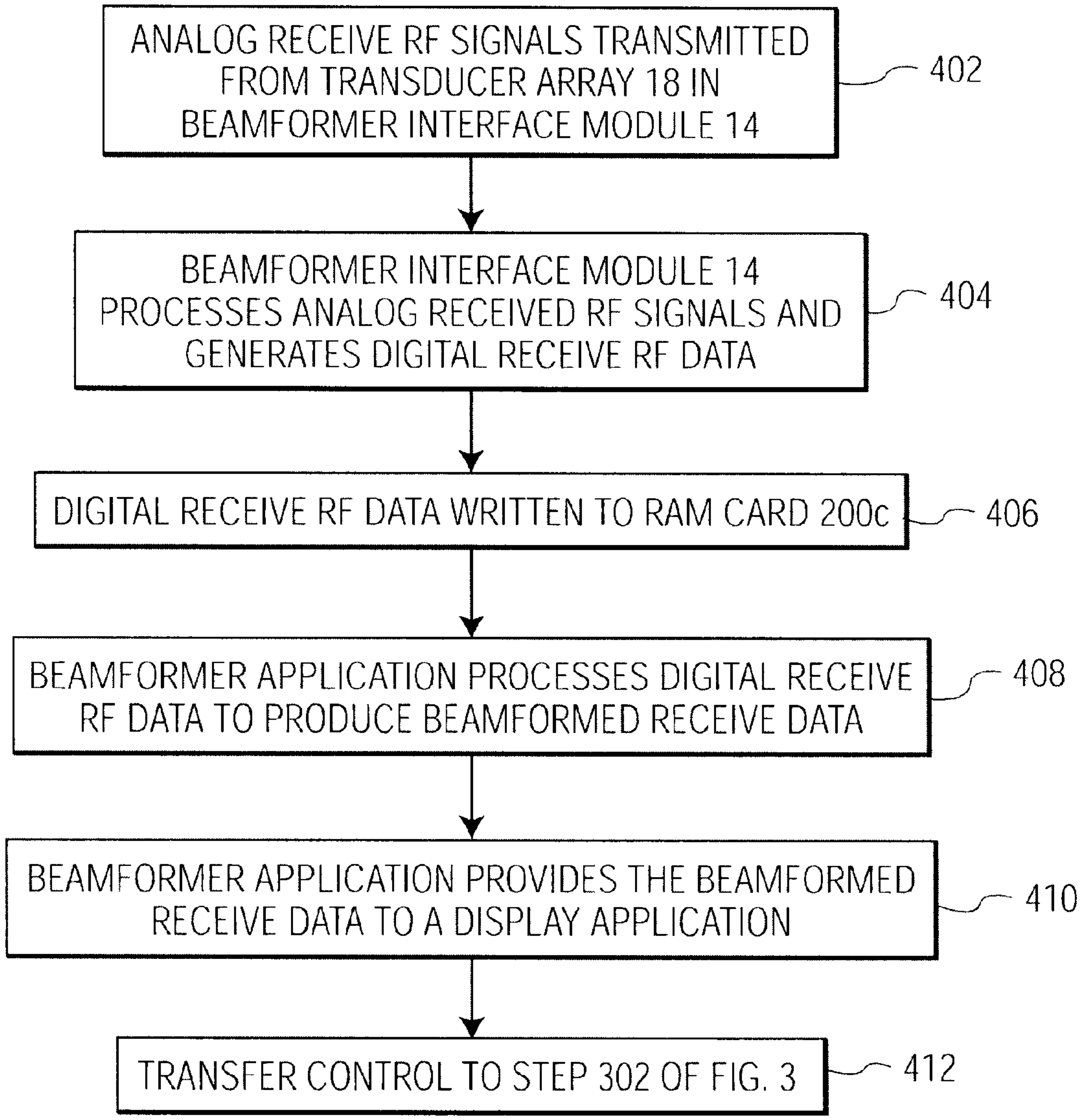

ANALOG RECEIVE RF SIGNALS TRANSMITTED FROM TRANSDUCER ARRAY 18 IN BEAMFORMER INTERFACE MODULE 14
402
BEAMFORMER INTERFACE MODULE 14 PROCESSES ANALOG RECEIVED RF SIGNALS AND GENERATES DIGITAL RECEIVE RF DATA
404
DIGITAL RECEIVE RF DATA WRITTEN TO RAM CARD 200c
406
BEAMFORMER APPLICATION PROCESSES DIGITAL RECEIVE RF DATA TO PRODUCE BEAMFORMED RECEIVE DATA
408
BEAMFORMER APPLICATION PROVIDES THE BEAMFORMED RECEIVE DATA TO A DISPLAY APPLICATION
410
TRANSFER CONTROL TO STEP 302 OF FIG. 3
412

FIG. 4

SYSTEM AND METHOD FOR INTERFACING AN ULTRASOUND TRANSDUCER WITH A COMPUTING DEVICE PERFORMING BEAMFORMING PROCESSING

FIELD OF THE INVENTION

The present invention generally relates to beamforming in ultrasound imaging systems, and in particular to a system and method for interfacing an ultrasound transducer with a computing device that performs beamforming processing.

BACKGROUND OF THE INVENTION

Ultrasound diagnostic technology generally relates to imaging of biological tissue by transmitting ultrasonic waves into tissue of a body being imaged, and receiving and processing ultrasonic wave echoes reflected from the tissue. An ultrasonic imaging system typically includes a transducer array provided within a probe, a beamformer and a display/user interface subsystem. The transducer array couples the acoustic energy into and out of the body, and converts the received waves into electrical signals ready for processing. The display subsystem processes and displays received signals. The user interface provides means for allowing a user to enter commands for controlling components of the system. The beamformer includes a transmit beamformer which controls operation of the transducer array for forming the transmitted acoustic energy into a directed beam in the body being imaged, and a receive beamformer for processing the received echoes for forming lines of data ready for processing by the display subsystem.

The beamformer has been implemented in a wide variety of technologies. For example, initially receive beamformers were implemented in analog electronics for performing fundamental delay and sum operations. As it became cost effective to do so beamformer design migrated to digital technology, in which the received RF signals were converted to digital format by A/D converters. The high-speed digital data was subsequently processed in dedicated VLSI devices.

With the evolving development of digital technologies and personal computers, portions of the display/user interface subsystem and the beamformer functions have been implemented directly in a computing device such as a personal computer (PC). The ability to upgrade PC hardware while maintaining software compatibility over generations of hardware upgrades is one of the advantages achieved by incorporation of the beamformer into the PC, in addition to integration with the display/user interface subsystem. However, the incorporation of the beamformer into the PC is limited due to the large data bandwidth, for example 128 channels of high speed RF data, processed by the beamformer.

Personal computers have architectures characterized by one or more central processors or microprocessors. These processors communicate to external devices by means of input/output (I/O) interface cards, which provide for the unique requirements of differing peripheral devices such as monitors, keyboards, etc. These peripheral devices are characterized by low data bandwidth relative to the needs of an ultrasound beamformer. Beamformer incorporation into the PC has required processing of the high speed RF data by external hardware devices for performing mathematical operations and convergence of the data into a narrow data stream provided to the PC via an I/O slot. However, the external hardware is expensive, requires custom design and manufacture for individual applications, and is limited in its ability to expand and adapt.

SUMMARY OF THE INVENTION

A beamformer for an ultrasound imaging system is provided, the ultrasound imaging system having a probe having a transducer array for transmitting and receiving analog signals, and a personal computer. The beamformer includes a beamformer software application module configured for execution by the computing device for performing at least partial beamforming processing on digital data transmitted between the transducer array and the computing device, and means for exchanging signals and data between the transducer array and the computing device and performing at least one of A/D and D/A conversions on the exchanged signals and data. In the preferred embodiment, the beamformer further includes a module integrated within architecture of the computing device, wherein the integrated module is preferably Random Access Memory (RAM) included in storage means of the computing device. The means for exchanging signals includes an interface module coupled between the transducer array and the computing device for performing the conversions. A method is further provided for performing a transmit beamforming process in an ultrasound system having a computing device and a probe including a transducer array, the method including the steps of performing transmit beamforming processing in the computing device in accordance with transmit settings to generate digital transmit data, storing the digital transmit in the data storage memory, retrieving the digital transmit data from the storage memory, converting the digital transmit data to analog transmit signals, and transmitting the analog transmit signals to the transducer array. A method is further provided for performing a receive beamforming process in an ultrasound system having a computing device including storage memory, a interface module and a probe including a transducer array, the method including the steps of receiving analog signals from the transducer array, converting the analog signals to digital data, storing the digital data in the storage memory, retrieving the digital data from the storage memory, and performing receive beamforming operations on the digital data by the computing device.

BRIEF DESCRIPTION OF THE DRAWINGS

Various embodiments of the invention will be described herein below with reference to the figures wherein:

FIG. **1** is a schematic representation of an ultrasonic system having an interface in accordance with an embodiment of the present invention;

FIG. **2A** is a block diagram of a interface module of the embodiment of FIG. **1**;

FIG. **2B** is a schematic representation of random access memory (RAM) provided in the embodiment of FIG. **1**;

FIG. **3** is a flow diagram of performance steps performed by a transmit portion of the beamformer in accordance with the present invention; and

FIG. **4** is a flow diagram of performance steps performed by a receive portion of the beamformer in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to FIG. **1**, an ultrasound imaging system **10** is shown, including a probe **12**, [GLOBAL] interface module **14** and computing device **16**. The probe **12** includes a commercially available array **18** of transducer elements, such as a single array, or a double array, and a static array or a mechanical array in accordance with design choice. The transducer array **18** may include a transmit transducer array and a receive transducer array, or the elements of the transducer array **18** may alternately perform transmit and receive functions. The interface module **14** interfaces the transducer array **18** to computing device **16**. The probe **12** communicates with the interface module **14** via a transducer cable **20** which couples to the interface module **14** via transducer connector **22** of cable **18** and cable connector **24** of interface module **14**. The interface module **14** connects with the computing device **16** via high bandwidth connector **28**. The interface module **14** is external to the computing device architecture, but may be internal to its physical structure by being enclosed within a housing of the computing device **16**. Preferably the interface module **14** is housed within a housing of computing device **16**.

The computing device **16** includes a central processor **40**, including one or more processors, connected at least to memory components and optional peripheral devices via I/O ports **48**. The computing device **16** is a device such as a personal computer (PC), a cellular telephone, a PDA, or other device having one or more microprocessors coupled to one or more memory components. The memory components include, for example, a high bandwidth memory **42** communicating with the central processor via a high bandwidth connection, such as Random Access Memory (RAM), and relatively low bandwidth memory components, such as hard drive **44** and external memory components (i.e. floppy discs, compact discs (CDs), etc.) connected via external memory drive(s) **46**. Peripheral devices may include devices such as a keyboard **49**, mouse **50**, display **52**, printer **54**, etc.

An integrated module **56** integrated into the high bandwidth memory **42** is further provided for storing data exchanged between the interface module **14** and the computing device **16**. The integrated module **56** thus integrated into the internal architecture of the computing device **16** has sufficient bandwidth and volume for accommodating reading and writing a high bandwidth and volume of data being processed in real time by the beamformer application software module **54**, in at least one of a transmit mode and a receive mode The integrated module **54** is preferably allocated specifically for use by the beamformer application software module **54**.

Preferably the computing device **16** is a commercially available personal computer having a commercially available interface standard for providing communication between the central processor **40** and the high bandwidth memory **42**. Preferably, the high bandwidth memory **42** is a RAM module, and the integrated module **54** is included in the RAM module. The high bandwidth capabilities of RAM provide the beamformer application software module **54** with the ability to perform beamformer transmit operations for controlling multiple elements of the transducer array **18**, and perform receive beamformer operations on received echo data on a virtual real time basis for preparing the data for display for a virtual real time display of the area being imaged.

A beamformer application software module **54** executable on the central processor **40** is provided, where the beamformer application software module **54** includes a series of executable instructions, also referred to as a beamformer application, for controlling transfer of data between the high bandwidth memory **42** and the integrated module **56**, and for controlling the interface module **14**, and for performing beamforming transmit and/or receive processing on data written to and/or read from the integrated module **56**. The beamforming processing performed by the beamformer application software module **54** may perform all of the beamforming processing performed in the ultrasound imaging system **10**, or may perform partial beamforming processing, where a remainder of the beamforming processing is performed in other components of the ultrasound imaging system **10**, such as by beamforming circuitry or a processor executing beamforming software provided in the other components of the ultrasound imaging system **10**.

The high bandwidth memory **42** is connected by at least one high bandwidth connector, such as bus **60**, to the central processor **40**. Furthermore, the high bandwidth memory **42** is connected by high bandwidth connector **28** to the interface module **14**. Coupling means, such as a bus, may be provided between the high bandwidth connector **28** and the high bandwidth memory **42**. In order to maximize bandwidth between the high bandwidth memory **42** and the interface module **14**, the high bandwidth connector **28** preferably connects directly to the high bandwidth memory, or the bus provided between the high bandwidth connector **28** and the high bandwidth memory **42** is kept short.

A communication link **62** is provided between the central processor **40** and the interface module **14** for transfer of control signals between the same. The control signals provide synchronization of data transfer between the central processor **40** and the interface module **14** via the integrated module **56**. Communication links between processors are known in the art. Communication via communication link **62** may include, for example, communication via a cable and one of the I/O ports **48**, or by writing and reading data from specifically allocated memory location(s) accessible by both processors, such as memory locations allocated in the high bandwidth memory **42** which are not accessible by the operating system.

FIG. **2A** shows the interface module **14** in greater detail. With reference to FIG. **1** and FIG. **2A**, the interface module **14** includes at least one of a receive module **230** and a transmit module **232**. For embodiments in which the receive module **230** and transmit module **232** are both included in the interface module **14**, switching means **234**, such as a transmit/receive (T/R) switch or a multiplexer, is included for directing signals between the transducer array **18** and the respective receive module **230** and transmit module **232**.

The interface module **14** further includes a processing unit **236** for controlling data transfer between the interface module **14** and the central processor **40** and/or for controlling operation of the interface module **14**. The processing unit **236** is preferably a microprocessor, but may also be other processing means, such as an analog circuit or a logic circuit. When the processing unit **236** is a microprocessor, the microprocessor stores and executes executable instructions for performing prescribed functions. Preferably, the executable instructions are downloaded from the computing device **16** to the microprocessor during power-up of the microprocessor.

Control processing for generating the control signals transmitted between the central processor **42** and the interface module **14**, as well as control signals for controlling internal functioning of interface module **14**, is performed by either the central processor **40** or the processing unit **236**, or a combination thereof. The control signals control, for example, switch means **234**; execution of read and write operations performed by the interface module **14** and or the central processor **40**; synchronization of data transfer between the interface module **14** and central processor **40** via the integrated module **56**, including notification of data locations in high speed memory **42** and timing of data transfers; transitioning between transmit and receive modes of the interface module **14** and/or the central processor **40**; and/or allocation of memory and/or notification of addresses of allocated memory within high bandwidth memory **42**, or a combination thereof.

The receive module **230** includes, for example, RF preamplifiers **238**, A/D converters **240**, as well as memories and clock generation circuits (not shown) for digitizing echo signals, i.e., analog RF receive signals received from the probe **12**, having sufficient bandwidth and dynamic range for subsequent beamforming operations to be performed at the computing device **16**. During a receive cycle, the receive module **230** receives a collection of analog RF receive signals, and converts the analog RF signals into Digital RF signals, and writes the Digital RF signals into designated locations receive in high bandwidth memory **42**.

The transmit module **232** includes, for example, memories and clock circuits (not shown), D/A converters **242**, high voltage RF amplifiers **244** for individually driving the transducer elements for generating acoustic signals. During a transmit cycle, the transmit module **232** reads digital beamformed transmit data from designated locations in high bandwidth memory **42**, converts the digital beamformed transmit data into analog beamformed transmit data, and transmits the analog beamformed transmit data to the transducer array **18** via cable **20**.

FIG. **2B** shows the high bandwidth memory **42** in greater detail. The high bandwidth memory **42** is preferably provided with at least a dual port function configured for supporting access to the high bandwidth memory **42** by two users, i.e. the central processor **40** and the interface module **14**. The dual port function is provided by two physical ports, or by one port controlled to act as two ports. The high bandwidth memory **42** is exemplified in FIG. **2B** to be a RAM, which may include single port or dual port RAM cards or chips (hereinafter referred to as cards) **200***a–d*, however it is to be understood that additional RAM cards may be included, or that a RAM card may be apportioned to allocate specific portions of the RAM card to perform the functions described for one or more of the cards **200***a–d*. Addresses of RAM cards **200***a–d* may be allocated for the specified functions physically or dynamically. RAM card **200***a* is preferably a commercially available RAM originally installed prior to installation of the integrated module. RAM card **200***a* is connected to the central processor **40** for high speed data transfers via bus **60** having a high bandwidth.

The integrated module **56** includes RAM cards **200***b–d* in the example shown in FIG. **2B**. A portion of the high bandwidth memory **42**, i.e., RAM cards **200***b–d* in this example, is allocated for the integrated module **56**. Alternatively, the integrated module **56** is an allocated portion of RAM card **200***a*. The integrated module **56** is installed within the computing device **16** in the same way that additional RAM is added when upgrading the RAM of a computing device, as is known by one skilled in the art. Upon installation of RAM cards **200***b–d*, the RAM cards **200***b–d* are connected to the central processor **40** via bus **60**. Preferably bus **60** is a standard interface for RAM and a central processor.

RAM cards **200***a–d* together form the high bandwidth memory **42**, where each location in each of the high bandwidth memory cards **200***a–d* has a unique address. The RAM card **200***a* is accessed by the operating system of the computing device **16**. The operating system controls swapping of information, such as data and executable programs in and out of RAM card **200***a*, allocating addresses to information stored in RAM card **200***a*.

The integrated module **56**, i.e., RAM cards **200***b–d*, is accessed by the central processor **40** upon execution of the beamformer application software module **54**. The beamformer application software module **54** specifically includes a series of executable instructions for performing read and/or write operations on the integrated module **56** by the central processor **40**. The addresses occupied by the integrated module **56** are unavailable to the operating system. The operating system is restricted from using the addresses allocated to the integrated module **56** for use by the beamformer application software module **54**. Preferably, the operating system is a commercially available operating system which can be programmed or customized to access only a first subset, of the RAM address locations available, while allowing an application running on the operating system to access only a second subset of the RAM address locations available which is mutually exclusive from the first subset.

The beamformer application software module **54** includes at least one of a beamformer transmit application module **54***a* and a beamformer receive application module **54***b*. For a beamformer application software module **54** that includes both beamformer transmit and receive application modules **54***a,b*, the integrated module **56** is further divided into a transmit RAM address subset and a receive RAM address subset, to which access is only allowed by the beamformer transmit and receive application modules **54***a,b*, respectively. In the exemplary RAM shown in FIG. **2B**, the addresses for the locations of RAM card **200***b* are allocated to exclusive use by the beamformer transmit application module **54***a*, and the addresses for the locations of RAM cards **200***c–d* are allocated to exclusive use by the beamformer receive application module **54***b*.

During the receive mode, the beamformer receive application module **54***b* of interface module **14** writes a first line of digital RF data into the integrated module **56** in a first set of designated locations of the receive RAM address subset, each channel of digital RF data being stored in a predetermined address range. The beamformer receive application module **54***b* reads the first line of digital RF data and performs receive beamforming processing on the digital RF data, including performing delay and summation processing, to generate receive beamformed data. Preferably, a next line of digital RF data is written into a second set of designated locations of the receive RAM address subset. Each subsequent line of received digital RF data is written alternately into the first and second sets of designated locations, so that while processing is being formed on data stored in one of the first and second sets of designated locations, received digital RF data is being stored in the other designated location.

The receive beamformed data is processed for display, such as by a display module of the beamformer software application module **54** or by a display application, for performing processes, such as, RF filtering, detection, color flow and Doppler detection, and scan conversion to rectangular coordinate format for display on a graphical monitor, as is known in the art. The receive beamformed data may be stored in the integrated module **56** for access by the display module or display application.

The inventive beamformer includes at least one of a transmit beamformer or a receive beamformer. The transmit beamformer includes at least the beamformer transmit application module **54***a*, RAM card **200***b*, transmit module **232**, processing unit **236**, communication link **62**, and cable **20** for providing data and signal transmission in the direction shown in FIG. **1** for the transmit mode. The receive beamformer includes at least the beamformer receive application module **54***b*, RAM cards **200***c* and **200***d*, receive module **230**, processing unit **236**, communication link **62**, and cable **20** providing data and signal transmission in the direction shown for the receive mode.

FIG. **3** shows performance steps performed by the transmit beamformer during the transmit mode. At step **302**, the beamformer application software module **54** checks beamformer transmit settings, which may be default or user entered values entered at initialization or during an imaging procedure, for selecting a desired mode of scanning, such as by selecting transmit waveforms and focusing parameters At step **304**, the beamformer transmit application module **54***a* determines from user entered parameters the scanning sequences and transmit waveforms which need to be performed by the transducer array **18**, performs transmit beamforming processing, including computing and applying appropriate delays respectively to each channel, and generates digital beamformed transmit data representing the selected scanning sequences and transmit waveforms and focal point. At step **306**, the beamformer transmit application module **54***a* stores the digital beamformed transmit data in the addresses of the RAM **42** (RAM card **200***b* in this example) allocated to use by the beamformer transmit application module **54***a*.

At step **308**, processing unit **236** is notified by the central processor that new digital beamformed transmit data is stored in RAM **42**, and the processing unit **236** initiates a read operation for reading the digital beamformed transmit data from the allocated addresses in RAM **200***b*. At step **310**, the interface module **14** processes the digital beamformed transmit data for converting the digital beamformed transmit data into analog beamformed transmit signals. The digital beamformed transmit data typically represents selected waveforms in accordance with focusing selections selected by user's settings or default values. The analog beamformed transmit signals are collections of individual electrical signals in the form of pulses for exciting the respective transducer elements. At step **312** the interface module **14** transmits the analog beamformed transmit signals via cable **20** to the transducer array **18**. At step **314**, control is transferred to step **402** of FIG. **4** for transitioning to the receive mode for receiving RF echo signals from the transducer array **18**.

FIG. **4** shows operation of the receive beamformer during the receive mode. Once the transducer array has begun transmission of acoustic energy, at step **402** real time analog RF receive signals are transmitted from the transducer array **18** via cable **20** to the interface module **14**. At step **404**, in interface module **14**, the analog RF receive signals are pre-amplified and converted from analog signals to digital RF receive data. At step **406**, the digital RF receive data is written, substantially in real time via connector **28**, to RAM card **200***c* for storage. Processing unit **236** notifies central processor **40** that new digital RF receive data is stored in RAM **42**. At step **408**, the beamformer application software module **54** performs beamforming and signal processing algorithms on the digital RF receive data stored in RAM **200***c*, and generates digital beamformed receive data. At step **410**, the digital beamformed receive data is processed for display, such as on a monitor. At step **412** control is transferred to step **302** of FIG. **3**. Subsequent lines of received data are stored and processed alternately in RAM cards **200***c* and **200***d*.

The beamformer of the present invention provides high bandwidth capabilities, the ability for the beamformer application software module **54** to be usable across several hardware generations and the ability to test and develop new prototype beamformer software applications without implementing new hardware configurations. Furthermore, by performing beamforming processing in a processor, the output of the beamformer processing may be provided in display coordinates, rather than in acoustic coordinates as typically provided by conventional beamformers, therefore eliminating the need to convert between acoustic coordinates and display coordinates.

It will be understood that various modifications may be made to the embodiments disclosed herein. Therefore, the above description should not be construed as limiting, but merely as exemplifications of preferred embodiments. Those skilled in the art will envision other modifications within the scope and spirit of the claims appended hereto.

What is claimed is:

1. A beamformer for an ultrasound imaging system, the ultrasound imaging system including a probe having a transducer array for transmitting and receiving analog RF signals, and a computing device, said beamformer comprising:

a beamformer software application module configured for execution by the computing device for performing at least partial beamforming processing on digital data transmitted between the transducer array and the computing device;

means for exchanging signals and data between the transducer array and the computing device and performing at least one of A/D and D/A conversions on the exchanged signals and data;

storage means integrated within an architecture of the computing device and having a subset of storage address locations available for an integrated module, the integrated module for storing data exchanged between the computing device and said means for exchanging signals and data; and

means for allocating the integrated module for exclusive use by the beamformer software application module for at least one of a transmit and a receive beamformer application.

2. The beamformer in accordance with claim **1**, wherein the means for exchanging signals includes an interface module coupled between the transducer array and the computing device for performing the conversions.

3. The beamformer in accordance with claim **2**, wherein the beamformer interface module includes a transmit module comprising:

means for receiving the digital data from the computing device;

means for converting the digital data to analog signals; and

means for transmitting the analog signals to the transducer array.

4. The beamformer in accordance with claim **2**, wherein the beamformer interface module includes a receive module comprising:

means for receiving the analog signals from the transducer array;

means for converting the analog signals to digital data; and

means for transmitting the digital data to the computing device.

5. The beamformer in accordance with claim **2**, wherein at least one of the computing device and the interface module includes means for generating control signals for synchronizing data exchange between the computing device and the interface module; and wherein the beamformer further comprises a communication link providing communication between the computing device and the interface module for propagating the control signals.

6. The beamformer in accordance with claim 5, wherein the beamformer further includes a module integrated within architecture of the computing device for storing digital signals exchanged between the computing device and the beamformer integrated module, and wherein the control signals synchronize data exchange between the computing device and the interface module via the integrated module.

7. The beamformer in accordance with claim 5, wherein the beamformer software application module includes means for generating a second set of control signals for controlling the interface module, and wherein the second set of control signals are transmitted via the communication link.

8. The beamformer in accordance with claim 1, wherein the integrated module is Random Access Memory (RAM).

9. The beamformer in accordance with claim 1, wherein the integrated module is configured for supporting access by both the computing device and an external module, the external module including at least one of a transmit module and a receive module.

10. The beamformer in accordance with claim 1, wherein the storage means of the computing device is interfaced with a central processor of the computing device via an interface, and wherein the integrated module is interfaced to the central processor via the interface.

11. The beamformer in accordance with claim 1, wherein the computing device is a personal computer, the storage means is a Random Access Memory (RAM) Module, and the integrated module is included in the RAM module.

12. The beamformer in accordance with claim 1, wherein the beamformer includes means for selecting transmit settings; and wherein the beamformer application software module includes means for performing transmit beamforming processing on selected transmit settings for generating digital beamformed transmit signals; and means for writing the digital beamformed transmit signals in the integrated module.

13. The beamformer in accordance with claim 1, wherein the beamformer application software module includes means for performing receive beamforming processing on analog signals transmitted by the transducer array which were converted to digital data and exchanged with the computing device by the means for exchanging signals.

14. A beamformer for an ultrasound imaging system, the ultrasound imaging system including a probe having a transducer array for transmitting and receiving analog signals, and a computing device having at least storage memory and a central processor coupled to the storage memory, said beamformer comprising:

an interface module coupled to the transducer array of the probe and to the storage memory for propagating signals between the transducer array and the interface module and for transmitting data between the interface module and a selected portion of the storage memory;

a beamformer software application module configured for execution by the central processor for performing at least partial beamforming processing on the data transmitted between the interface module and the selected portion of the storage memory, wherein the selected portion of the storage memory includes a subset of storage address locations available for an integrated module, the integrated module for storing data exchanged between the interface module and the selected portion of the storage memory; and

means for allocating the integrated module for exclusive use by the beamformer software application module for at least one of a transmit and a receive beamformer application.

15. The beamformer in accordance with claim 14, wherein the storage memory of the computing device includes Random Access Memory (RAM), and the selected portion of the storage memory is included in the RAM.

16. The beamformer in accordance with claim 14, wherein the beamformer interface module includes means for exchanging signals and data between the transducer array and the selected portion of the memory and performing at least one of A/D and D/A conversions on the exchanged signals.

17. A method for performing a transmit beamforming process in an ultrasound system having a computing device and a probe including a transducer array, the method comprising the steps of:

allocating an integrated module within the computing device for exclusive use by a beamformer software application module for a transmit beamformer application;

performing transmit beamforming processing in the computing device in accordance with user entered transmit settings to generate digital beamformed transmit data;

storing the digital beamformed transmit data in a storage memory, the storage memory being integrated within an architecture of the computing device and having a subset of storage address locations available for the integrated module, the integrated module for storing data exchanged between the computing device and the probe for exchanging signals and data;

retrieving the digital beamformed transmit data from the storage memory;

converting the digital beamformed transmit data to analog transmit signals; and

transmitting the analog transmit signals to the transducer array.

18. A method for performing a receive beamforming process in an ultrasound system having a computing device including storage memory, an interface module and a probe including a transducer array, the method comprising the steps of:

allocating an integrated module within the computing device for exclusive use by a beamformer software application module for a receive beamformer application;

receiving analog RF receive signals from the transducer array;

converting the analog RF receive signals to digital RF receive data;

storing the digital RF receive data in the storage memory, the storage memory being integrated within an architecture of the computing device and having a subset of storage address locations available for the integrated module, the integrated module for storing data exchanged between the computing device and the probe for exchanging signals and data;

retrieving the digital RF receive data from the storage memory; and

performing receive beamforming operations on the digital RF receive data by the computing device.

19. An interface module of an ultrasound imaging system having a transducer array for transmitting and receiving analog RF signals, and a computing device that executes

beamforming software for performing at least partial beamforming processing on digital data transmitted between the transducer array and the computing device, the interface module comprising:

means for exchanging signals and data between the transducer array and the computing device via a storage memory, wherein a selected portion of the storage memory includes a subset of storage address locations available for an integrated module, the integrated module for storing data exchanged between the interface module and the selected Portion of the storage memory;

means for allocating the integrated module for exclusive use by a beamformer software application module for at least one of a transmit and a receive beamformer application; and

means for performing at least one of A/D and D/A conversions on the exchanged signals and data.

20. A beamformer application software module executable on a computing device of an ultrasound imaging system having a transducer array for transmitting and receiving analog RF signals, the computing device, and an interface module for exchanging signals and data between the transducer array and the computing device, and for performing at least one of A/D and D/A conversions on the exchanged signals and data, the beamformer software application module comprising:

executable beamforming software for performing at least partial beamforming processing on digital data transmitted between the transducer array and the computing device;

means for synchronizing the exchange of signals between the interface module and the computing device; and

means for allocating an integrated module of a storage means for exclusive use by a beamformer software application module for at least one of a transmit and a receive beamformer application.

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专利名称(译)	用于将超声换能器与执行波束形成处理的计算设备接口的系统和方法		
公开(公告)号	US6716171	公开(公告)日	2004-04-06
申请号	US10/261890	申请日	2002-09-30
[标]申请(专利权)人(译)	布洛克FISHER GEORGE		
申请(专利权)人(译)	布洛克-FISHER GEORGE		
当前申请(专利权)人(译)	皇家飞利浦电子股份有限公司		
[标]发明人	BROCK FISHER GEORGE		
发明人	BROCK-FISHER, GEORGE		
IPC分类号	G01S15/00 G01S15/89 G01S7/52 A61B8/00 G01N29/26 G01S7/523		
CPC分类号	G01S7/52034 G01S15/8906 A61B8/00		
其他公开文献	US20040064044A1		
外部链接	Espacenet USPTO		

摘要(译)

提供了一种用于超声成像系统的波束形成器，该超声成像系统具有探头，该探头具有用于发送和接收模拟信号的换能器阵列，以及个人计算机。波束形成器包括：波束形成器软件应用模块，被配置为由计算设备执行，用于对在换能器阵列和计算设备之间传输的数字数据执行至少部分波束形成处理，以及用于在换能器阵列和计算设备之间交换信号和数据的装置。并且对交换的信号和数据执行A / D和D / A转换中的至少一个。在优选实施例中，波束形成器还包括集成在计算设备的体系结构内的模块，其中集成模块优选地是包括在计算设备的存储装置中的随机存取存储器（RAM）。还提供了一种用于在具有计算的超声系统中执行发射波束形成过程的方法装置和包括换能器阵列的探头，该方法包括以下步骤：根据发射设置在计算装置中执行发射波束形成处理以产生数字发射数据，将数字发射存储在数据存储存储器中，从中检索数字发射数据存储存储器，将数字发送数据转换为模拟发送信号，并将模拟发送信号发送到换能器阵列。还提供了一种用于在超声系统中执行接收波束成形过程的方法，该超声系统具有包括存储存储器，接口模块和包括换能器阵列的探头的计算装置，该方法包括从换能器阵列接收模拟信号，转换模拟信号到数字数据，将数字数据存储在存储器中，从存储器中检索数字数据，以及通过计算对数字数据执行接收波束成形操作设备。