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[54] **ULTRASONIC DIAGNOSTIC IMAGING SYSTEM WITH THIN CABLE ULTRASONIC PROBES**

[75] Inventors: **Lauren S. Pflugrath**, Seattle; **Leo R. Catallo**; **Juin-Jet Hwang**, both of Mercer Island, all of Wash.

[73] Assignee: **ATL Ultrasound**, Bothell, Wash.

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[22] Filed: **Nov. 20, 1998**

[51] **Int. Cl.**[7] **A61B 8/02**

[52] **U.S. Cl.** **600/447**

[58] **Field of Search** 600/437, 443, 600/432, 441, 455–456, 454; 73/607, 625–626

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Primary Examiner—Francis J. Jaworski
Attorney, Agent, or Firm—W. Brinton Yorks, Jr.

[57] **ABSTRACT**

An ultrasonic diagnostic imaging system is provided with scanheads having a reduced size cable by virtue of the performance of at least some of the beamforming in the scanhead. The need to individually couple signals from all of the elements of the transducer array of the scanhead is eliminated, and the size of the scanhead cable correspondingly reduced, by the coupling of combined, beamformed signals through the cable to an ultrasound system.

27 Claims, 5 Drawing Sheets

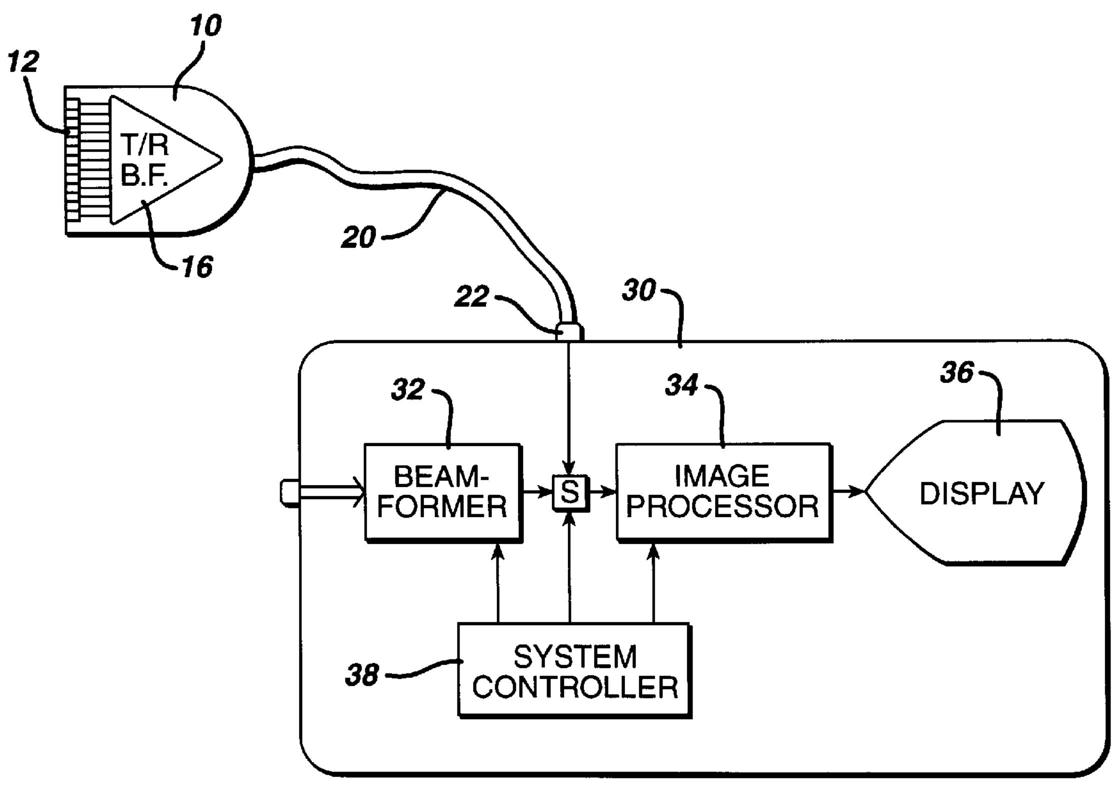


FIG. 1 PRIOR ART

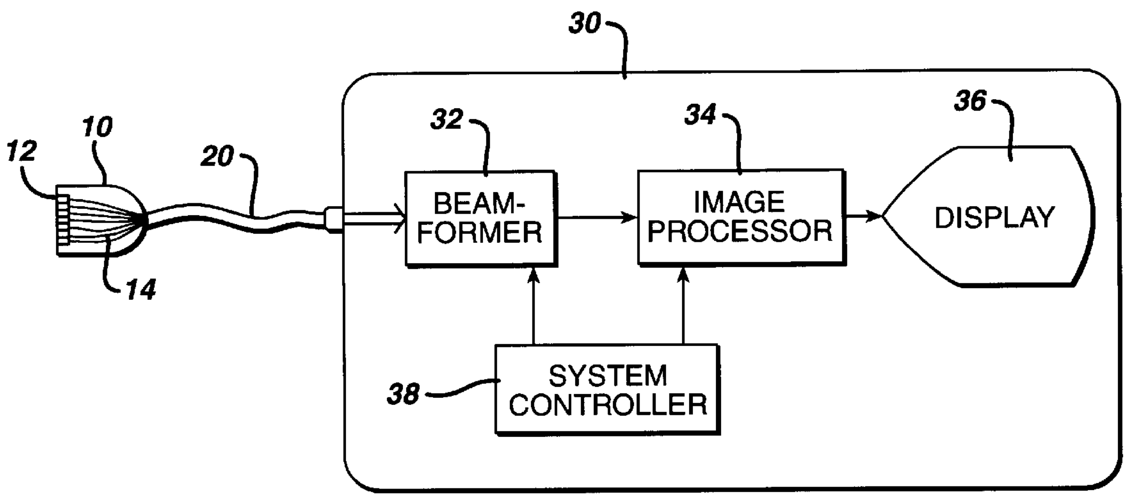


FIG. 2

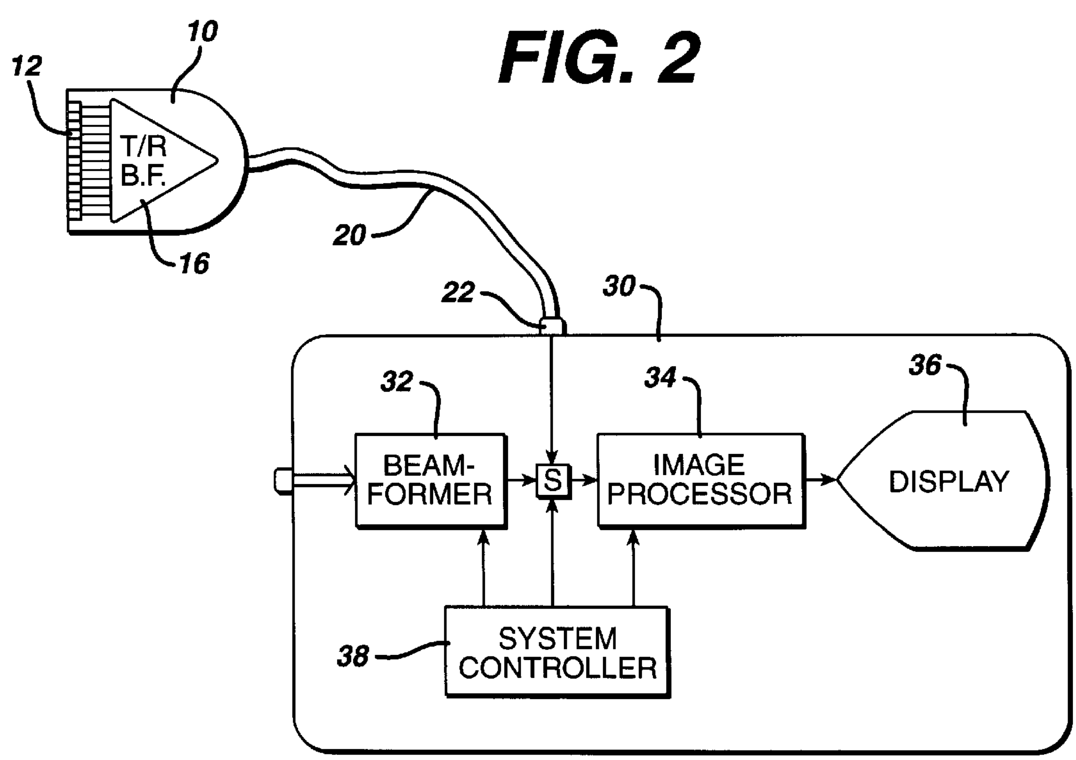
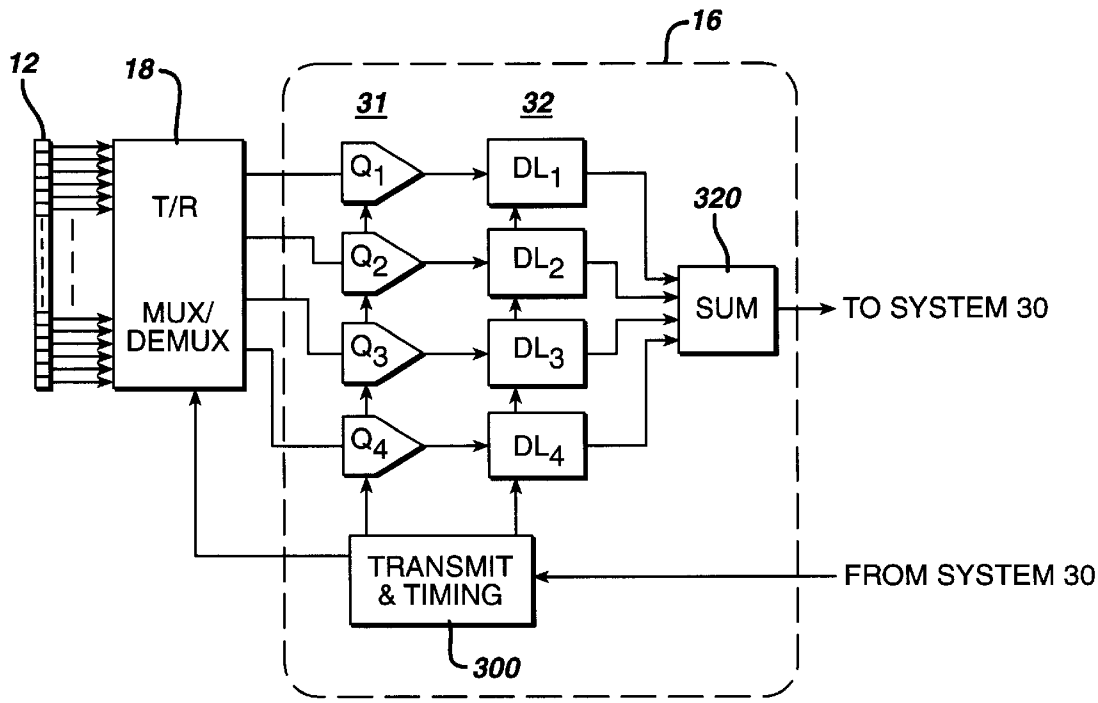


FIG. 3


16
12
18
31
32
T/R
MUX/
DEMUX
Q1
Q2
Q3
Q4
DL1
DL2
DL3
DL4
320
SUM
TO SYSTEM 30
TRANSMIT
& TIMING
FROM SYSTEM 30
300

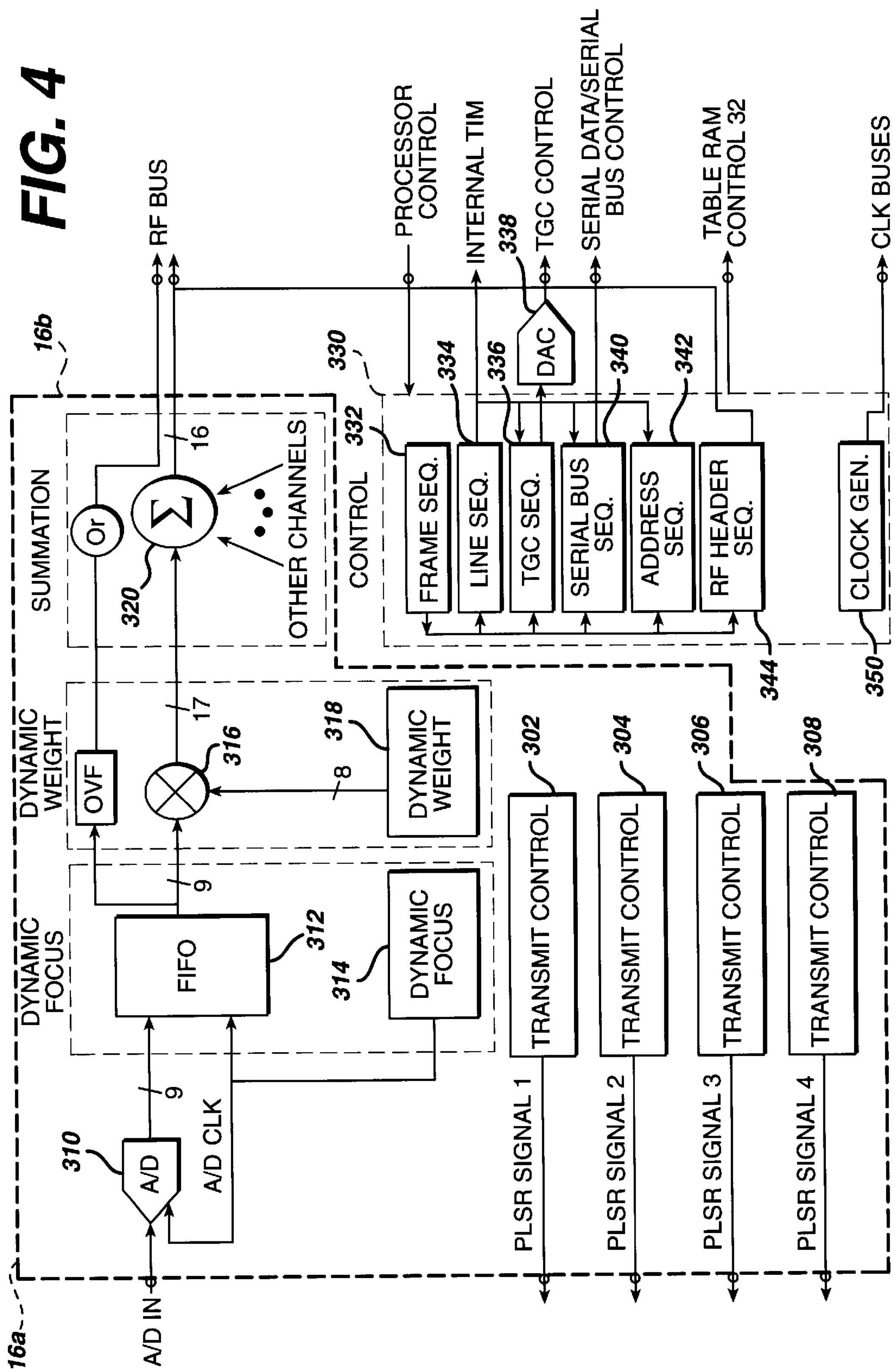

16a
16b
A/D IN
A/D
310
A/D CLK
9
DYNAMIC FOCUS
FIFO
312
DYNAMIC FOCUS
314
DYNAMIC WEIGHT
OVF
316
17
8
DYNAMIC WEIGHT
318
SUMMATION
Or
320
16
OTHER CHANNELS
RF BUS
CONTROL
330
332
FRAME SEQ.
334
LINE SEQ.
336
TGC SEQ.
SERIAL BUS SEQ.
340
ADDRESS SEQ.
342
RF HEADER SEQ.
344
CLOCK GEN.
350
DAC
338
PROCESSOR CONTROL
INTERNAL TIM
TGC CONTROL
SERIAL DATA/SERIAL BUS CONTROL
TABLE RAM CONTROL 32
CLK BUSES
TRANSMIT CONTROL
302
TRANSMIT CONTROL
304
TRANSMIT CONTROL
306
TRANSMIT CONTROL
308
PLSR SIGNAL 1
PLSR SIGNAL 2
PLSR SIGNAL 3
PLSR SIGNAL 4

FIG. 4

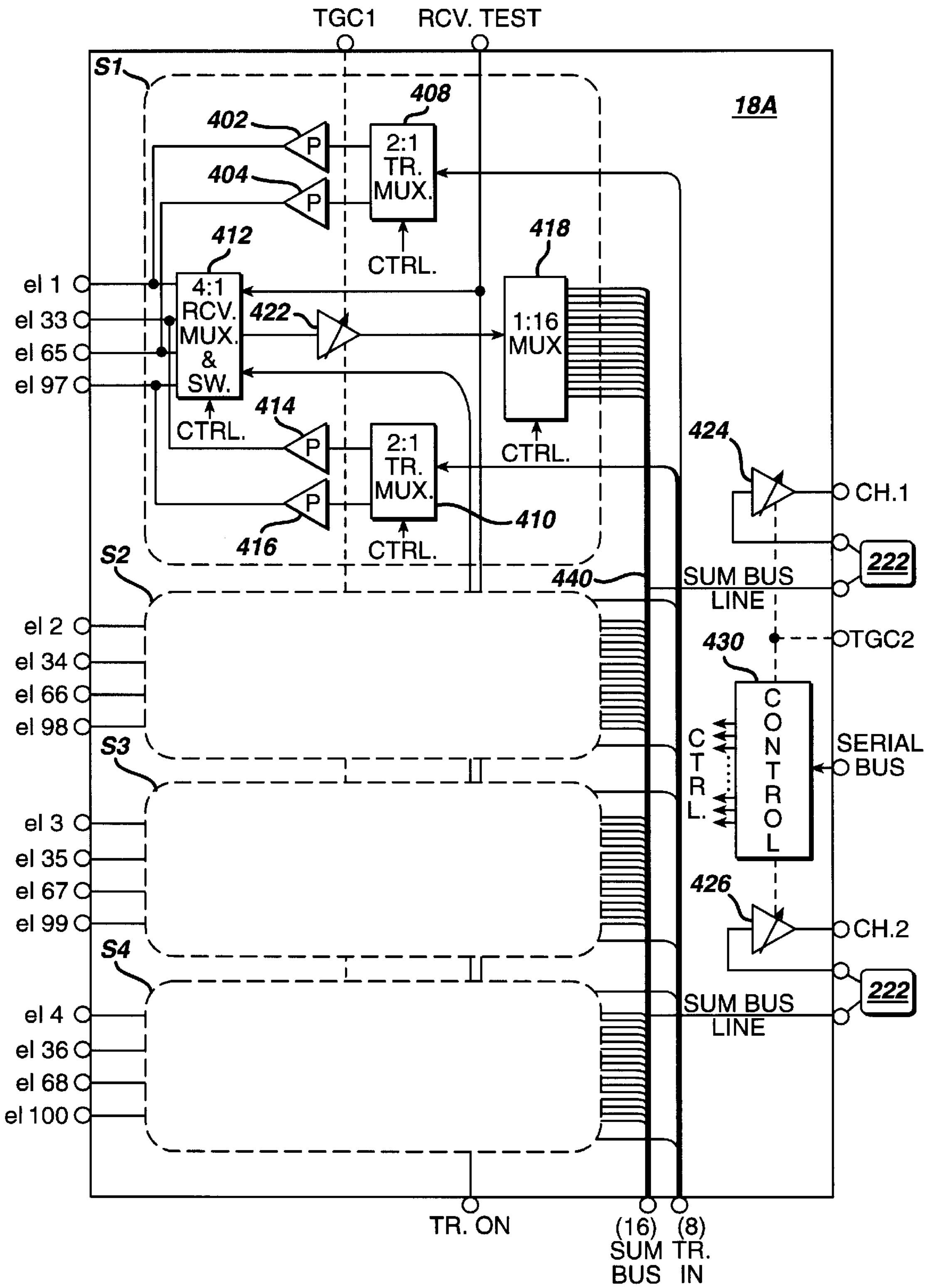

TGC1
RCV. TEST
S1
18A
402
404
408
2:1 TR. MUX.
P
CTRL.
412
418
4:1 RCV. MUX. & SW.
422
1:16 MUX
el 1
el 33
el 65
el 97
CTRL.
414
2:1 TR. MUX.
416
410
424
CH.1
222
SUM BUS LINE
440
S2
el 2
el 34
el 66
el 98
TGC2
430
CONTROL
CTRL.
SERIAL BUS
S3
el 3
el 35
el 67
el 99
426
CH.2
S4
el 4
el 36
el 68
el 100
TR. ON
(16) SUM BUS
(8) TR. IN

FIG. 5

FIG. 6a

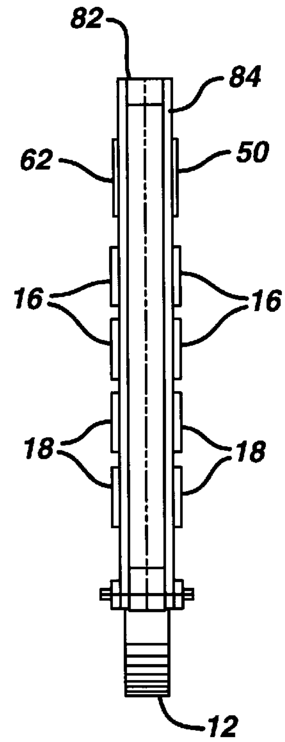
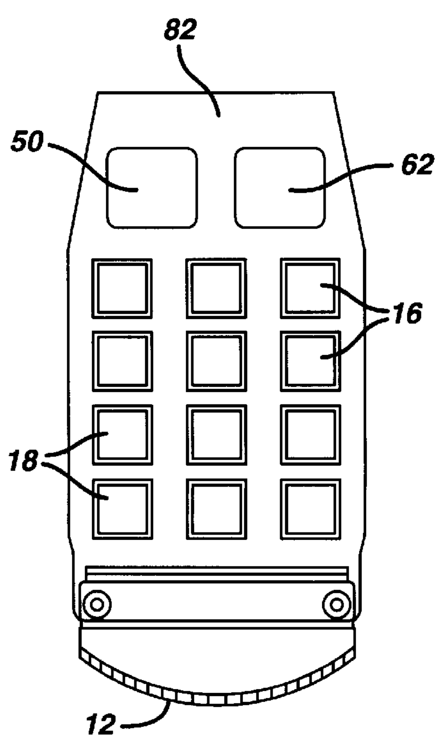


FIG. 6b



ULTRASONIC DIAGNOSTIC IMAGING SYSTEM WITH THIN CABLE ULTRASONIC PROBES

This invention relates to ultrasonic diagnostic imaging systems and, in particular, to ultrasonic diagnostic imaging systems in which the scanning of patients is done by thin cable scanheads.

Ultrasonic diagnostic imaging systems have traditionally been thought of as having two major constituent parts: a probe or scanhead, and the mainframe processor or system. The probe contains the piezoelectric transmitter and receiver of ultrasonic energy which is used to scan the patient's body. The system contains the sophisticated electronic controllers and processors which control the probe and turn the received echo signals into diagnostic images and information. But there is one additional ever-present component: the cable which connects the probe to the system, through which power and signals are coupled between the probe and system.

The probe cable has taken many forms as it has evolved over the years, and has had varying impacts on physician and patient comfort and convenience. Early products which only were used for audio Doppler or A-line (single line) imaging needed very few wires in the cable. Since the probes for such products generally used single element or single piston transducers, sometimes referred to as "pencil probes," signal and ground wires often sufficed as a complete cable. Such a probe had an unsteered, fixed focus along a single beam. The user adjusted the probe by physically moving it to a different position or offsetting it from the body with an acoustic standoff. While the thin, light cable was convenient to lift and maneuver, the caliber of the diagnostic information obtained was minimal.

The advent of B arm systems took convenience in a different direction. In these systems the probe was attached to the end of an articulated arm which provided probe position information for two dimensional imaging. The step-up in diagnostic image quality was at the expense of the articulated arm, which constrained imaging to its range of movement. Merged into the articulated arm, the cable was virtually unnoticeable in the ungainly mechanism.

Greater freedom of movement returned with the development of the mechanical sector scanner probe. The mechanical sector scanner oscillated the transducer back and forth to scan the image field, and the oscillating mechanism provided the spatial orientation for two dimensional imaging. A single piston transducer with two wires, signal and ground, was needed, as well as wires to power and control the oscillating mechanism and send the spatial orientation signals to the system. The hand-held probe was convenient, but the cable was beginning to grow in size.

Cable growth accelerated considerably with the advent of solid-state or array probes. In the array probes the transducer comprises an array of dozens or hundreds of elements which are individually controlled to electronically steer and focus the ultrasound beam. But with individual control comes the need for individual wires: a 128 element transducer probe can require a cable with 128 individual wires. Since received echo signals are generally of very low levels, the wires are not simply stranded wires, but coaxial lines, each with its own signal line and conductive shield. While various multiplexing schemes in the probe have been used to reduce the number of wires in the cable, these schemes can have adverse consequences for performance criteria such as frame rate, aperture size, and control complexity. Accordingly it would be desirable to reduce the size of the probe cable, thereby improving clinician and patient convenience but without incurring any performance penalties.

In accordance with the principles of the present invention, an ultrasonic diagnostic imaging system is presented in which the size of the probe cable is significantly reduced, providing improved convenience for the clinician and patient. This convenience is brought about by the inclusion of a beamformer integrated circuit in the probe case, eliminating the need to couple individual transducer element signals to the mainframe system. With the receive beam being at least partially formed in the probe, only the beamformed echoes need be transmitted to the mainframe system, replacing the 128 wires from the individual transducer elements of the array probe mentioned above with as few as one analog line or one multibit digital line.

In the drawings:

FIG. **1** illustrates in block diagram form the conventional configuration of an ultrasonic probe, cable, and ultrasonic imaging system;

FIG. **2** illustrates an ultrasonic probe with an integral beamformer operatively connected to an ultrasonic imaging system in accordance with the principles of the present invention;

FIG. **3** is a more detailed block diagram of the ultrasonic probe of FIG. **2**;

FIG. **4** illustrates in block diagram form a digital beamforming integrated circuit suitable for use in the ultrasonic probe of FIG. **3**;

FIG. **5** illustrates in block diagram form a multiplexer suitable for use in the ultrasonic probe of FIG. **3**; and

FIGS. **6*a*** and **6*b*** illustrate the internal array and integrated circuit packaging of a probe of the present invention.

Referring first to FIG. **1**, a conventional ultrasonic probe, cable and imaging system arrangement is shown in block diagram form. The ultrasonic probe **10** includes a transducer array **12**. Conductors **14** connect individual elements of the transducer array to conductors inside a cable **20**, which connects to an ultrasonic imaging system **30**. The conductors of the cable are electrically connected to a beamformer **32** in the imaging system, which controls the timing of the pulsing of the elements of the transducer array, and delays and sums received echo signals from the transducer elements to form coherent beams of echo signals. The beamformed echo signals are coupled to an image processor **34** where they are processed to form an image of tissue or flow within the body of the patient being scanned. The resultant ultrasonic image is displayed on an image display **36**. Coordination of the processing and data flow of the beamformer **32** and image processor **34** is provided by a system controller **38**, which receives instructions from a user by way of various user controls.

While the elements of the transducer array **12** are shown directly wired to the conductors of the cable in FIG. **1**, multiplexers can be included within the probe between the array elements and the cable to reduce the number of cable conductors. It is then necessary to control the multiplexers from the ultrasound system with control lines, so that the cable conductors are multiplexed to the elements of the current active aperture each time the probe is transmitting or receiving ultrasonic signals.

FIG. **2** illustrates an embodiment of the present invention in which the beamforming for both ultrasonic transmission and reception is done within the probe, significantly reducing the number of conductors needed within the cable **20**. The elements of the transducer array **12** are coupled to a transmit/receive beamformer **16**, which controls the timing, steering and focusing of the ultrasonic beams transmitted by the array and the beamforming of coherent echo signals from the signals received by the array elements. The formed beam, rather than signals from each transducer element, are coupled through the cable **20** for image processing and display by the ultrasound system **30**. The cable **20** will also convey control information from the system controller **38** which commands the beamformer as to the specifics of the image being scanned. This control information can be conveyed by a serial digital line in the cable and the information stored in beamformer registers as discussed below. The cable will also carry supply voltages for the beamformer and the transducer array. Even when the transmit/receive beamformer **16** is a digital beamformer producing multibit digital data, the number of cable conductors is still substantially reduced as compared to the conductors required for a conventional **64**, **96** or **128** element transducer array.

Since the received ultrasound beam is formed in the probe **10** in FIG. **2**, the probe does not need to use the beamformer **32** in the ultrasound system **30**. The beamformed echo signals produced by the probe **10** can be coupled directly to the image processor **34** for immediate processing and subsequent display. In the embodiment of FIG. **2** this is accomplished by a switch S which is switched under control of the system controller to connect the beamformed echo signals from probe **10** to the image processor, rather than signals produced by the system beamformer **32**. As is conventional, a "personality chip" in the probe **10** or its system connector **22** notifies the user of the characteristics of the probe **10** and selection of probe **10** by the user at the user controls causes the system controller to command the probe to operate and connect its echo information to the image processor **34**.

FIG. **3** illustrates an embodiment of an ultrasonic probe with a beamformer **16** and a transmit/receive multiplexer/demultiplexer **18**. The beamformer **16** includes transmit and timing circuitry **300** which controls the timing of the ultrasonic waves transmitted by the elements of the transducer array **12**. The transmit and timing circuitry receives command signals from the ultrasound system **30** to control the probe to produce the type of image desired by the user. The transmit and timing circuitry also directs the transmit/receive multiplexer/demultiplexer to select the desired active aperture of the array. The transmit and timing circuitry can also control the nature of the transmitted wave, for instance, transmitting different waves for B mode and Doppler imaging. The timing and control signals are applied to the multiplexer/demultiplexer **18** and elements of the array are excited at the proper times to steer and focus the desired transmit beam.

Echoes received by the array elements are converted to electrical signals by the elements and directed by the multiplexer/demultiplexer **18** to the receive beamforming circuitry of the beamformer **16**. The received echo signals from the transducer elements of the active receive aperture are coupled to individual channels of the beamformer; the drawing of FIG. **3** illustrates a four channel beamformer. The preferred beamformer is fabricated in integrated circuit form and preferably will contain a multiple of four channels in each beamformer chip. Four, eight, or sixteen channel beamformer chips may readily be employed for most large element count arrays. The preferred beamformer is a sampled data beamformer which may use either sampled analog or digital technology. In either case each channel of the beamformer includes an initial quantizing stage **31** followed by a delay line stage **32**. The outputs of the delay line stages are coupled to a summing circuit **320** which combines the delayed echo signals to form the receive beam. The four channel beamformer illustrated in FIG. **3** includes four quantizing stages Q_1, Q_2, Q_3, and Q_4 followed by four delay line stages DL_1, DL_2, DL_3, and DL_4. The coherent echo signals at the output of the summing circuit **320** are coupled to the ultrasound system **30** for image processing and display.

When the receive beamformer is of the sampled analog variety the quantizing stages comprise sample-and-hold circuits which sample the received echo signals at times indicated by the transmit and timing circuitry **300**. The sampled analog signal voltages are then appropriately delayed by charge coupled device (CCD) bucket brigade delay lines as the delay line stages. The delay time is controlled by the transmit and timing circuitry **300** in any of several ways. One is to select one of a plurality of input taps to the CCD delay line to which the sampled voltage is applied. Another is to select one of a plurality of output taps from the stages of the CCD delay line to the summing circuit **320**. In either case the selection of the tap will select the number of stages through which the voltage sample will be shifted and hence delayed. A third delay technique is to vary the frequency at which samples are shifted through the CCD stages: a lower frequency imparts a longer delay to the samples being shifted. The summed output signals may be digitized by an analog to digital converter in the probe and transmitted to the ultrasound system **30** in digital form, or the analog signals may be transmitted to the ultrasound system **30** and converted into digital echo samples in the ultrasound system. The latter approach would require only a single output signal conductor in the cable **20**.

When the receive beamformer is a digital beamformer, the quantizing stages comprise analog to digital converters which convert the per element analog signals to digital samples at sampling times indicated by the transmit and timing circuitry **300**. The digital echo samples are then digitally delayed by a digital delay line which can take the form of a random access memory, shift register, or digital FIFO register. The delay of each digital delay stage is controlled by the transmit and timing circuitry **300** which controls the write-read interval of a sample in memory or the shift frequency of a shift register or FIFO register. The delayed samples at the outputs of the digital delay lines are digitally summed and forwarded to the ultrasound system **30**.

A digital beamformer suitable for use in the probe of FIG. **3** is shown in block diagram form in FIG. **4**. This drawing shows one section **16***a* of a beamformer integrated circuit **16**. There are eight such sections on the beamformer I.C. to provide beamforming of the signals of eight transducer elements from the multiplexer/demultiplexer **18**. Each echo signal from the multiplexer/demultiplexer is coupled to the input of an A/D converter **310**, where the echo signals are converted to digital data. The A/D converters are located on the same integrated circuit as the beamformer itself, which minimizes the external connection pins of the integrated circuit. Only one analog input pin is required for each beamformer channel, and only one set of digital output pins is required for the coherently summed output signal. The digital data from the A/D converter for each element (or each pair or group of elements in a folded or coarse aperture) is shifted into a first in, first out (FIFO) register **312** by a clock signal A/D CLK. The A/D CLK signal is provided by a dynamic focus controller **314** which defers the start of the clock signal to provide an initial delay, then controls the signal sampling times to provide dynamic focusing of the received echo signals. The length of the FIFO register **312** is determined by the transducer center frequency, the aperture size, the curvature of the array, and the beam steering requirement. A higher center frequency and a curved array will reduce the steering delay requirement and hence the length of the FIFO register, for instance. The delayed echo signals from the FIFO register **312** are coupled to a multiplier **316** where the echo signals are weighted by dynamic weight values provided by a dynamic weight controller **318**. The dynamic weight values weight the echo signals in consideration of the effects of the number of active elements, the position of an element in the aperture, and the desired apodization function, as the aperture expands by the inclusion of additional outer elements as echoes are received from increasing depths along the scanline. The delayed and weighted echo signals are then summed with appropriately delayed and weighted echo signals from other elements and echo signals from any other delay stages which are coupled in cascade through a summer **320**. The beamformed echo signals, together with synchronous overflow bits, are produced as output scanline data on an RF data bus. Accompanying each sequence of scanline echo signals is identifying information provided by an RF header sequencer on the I.C., which identifies the type of scanline data being produced. The RF header can identify the scanline as B mode echo data or Doppler data, for instance.

Other digital and sampled data storage devices can be used to provide the beamformer delays, if desired. A dual ported random access memory can be used to store the received digital echo samples, which are then read out from the memory at times or in sequences which provide the desired delay for the signals from the transducer elements.

Each section **16*a*** of the beamformer I.C. includes transmit control circuits **302–308** for four transducer elements of the array. The eight sections of the I.C. thus provide transmit control for 32 elements of the array at the same time, thereby determining the maximum transmit aperture. The transmit control circuits produce waveforms of predetermined durations and periodicities which activate multiplexer pulsers at the appropriate times to produce a transmitted acoustic signal which is steered in the desired direction and focused at the desired depth of focus.

The beamformer I.C. **16** includes a common control section **330** which provides overall control for the transmission and receive functions of the eight beamformer channels on the I.C. The control section **330** is controlled by and receives data under control of the system controller **38** located in the ultrasound system **30**. The control data tables for a particular image frame are stored in memory in the ultrasound system and are loaded into the control section **330** under command of the system controller. The control section **330** includes a number of sequencers for the probe's transmit and receive functions. The frame sequencer **332** produces information used by other sequencers which identifies the type of image frame which is to be produced. The frame sequencer may, for example, be loaded with data that defines the next frame as B mode scanlines interspersed between groups of four Doppler scanlines, and that the sequence of scanlines will be all odd numbered scanlines followed by all even numbered scanlines. This information is supplied to the line sequencer **334**, which controls the timing required to acquire the desired scanlines. During the scanline acquisition the line sequencer controls the TGC sequencer **336** so that it will produce the desired sequence of TGC control data. The TGC control data from the TGC sequencer is converted to a voltage signal by a digital to analog converter (DAC) **338** and applied to the TGC control input terminal(s) of the multiplexer/demultiplexer **18**. The address sequencer **342** controls the loading of data for a new scanline into various realtime registers of the beamformer such as the registers of the TGC sequencer, the dynamic focus **314** and dynamic weight controllers **318**, and the serial bus sequencer **340**, which produces serial data on a serial bus for control registers of the multiplexer/demultiplexer **18**. All registers on the beamformer I.C. which perform real time functions are double buffered. The registers of the transmit/receive multiplexer/demultiplexer **18** are also double buffered so that control data for multiplexing and TGC control can be put on the serial bus and loaded into multiplexer/demultiplexer registers during the line preceding the scanline for which the control data is used.

The beamformer I.C. includes in its control section a clock generator **350** which produces a plurality of synchronous clock signals from which all operations of the probe are synchronized. A crystal oscillator (not shown) is coupled to the beamformer I.C. **16** to provide a basic high frequency such as 60 MHz from which all of the clock signals of the probe may be derived.

Further details on the operation of the beamformer I.C. and its sequencers may be found in U.S. Pat. No. 5,817,024.

A transmit/receive multiplexer I.C., suitable for use as multiplexer/demultiplexer **18** in the probe of FIG. **3**, is shown in FIG. **5**. The signal paths of the multiplexer I.C. **18**A are divided into four identical sections **S1**, **S2**, **S3**, and **S4**. In this drawing section Si is shown in internal detail. The section **S1** includes two 2:1 transmit multiplexers **408** and **410**, each of which is responsive to a pulser signal on one of eight Transmit In lines. Each 2:1 transmit multiplexer has two outputs which drive pulsers **402**, **404**, and **414**, **416**, the outputs of which are coupled to multiplexer I.C. pins to which transducer elements are connected. In the illustrated embodiment the 2:1 transmit multiplexer **408** is coupled to drive either element **1** or element **65**, and the 2:1 transmit multiplexer **410** is coupled to drive either element **33** or element **97**. The 2:1 transmit multiplexers of the other sections of the multiplexer I.C. **18**A are each similarly coupled to four transducer elements. With a separate pulser for each transducer element, the multiplexer I.C. **18**A can independently and simultaneously drive eight of the sixteen transducer elements to which it is connected.

The transducer element pins to which the pulsers of each section are coupled are also coupled to the inputs of a 4:1 receive multiplexer and switch **412**. When the pulsers are driving the transducer elements during ultrasound transmission, a signal on a Transmit On line which is coupled to all of the 4:1 Receive Multiplexers and Switches on the multiplexer I.C. switches them all into a state which presents a high impedance to the high voltage drive pulses, thereby insulating the rest of the receive signal paths from these high voltage pulses. All of the 4:1 receive multiplexers and switches of the multiplexer I.C. are also coupled to a Receive Test pin of the multiplexer I.C., by which a test signal can be injected into the receive signal paths and propagate through the receiver system. During echo reception each 4:1 receive multiplexer and switch couples the signals of one of the four transducer elements to which it is coupled to a 1:16 multiplexer **418** by way of a first TGC stage **422**. The gain of the first TGC stages on the multiplexer I.C. is controlled by a voltage applied to a TGC1 pin of the multiplexer I.C. which, in a constructed embodiment, comprises two pins for application of a differential control voltage. The 1:16 multiplexers of each section of the multiplexer I.C. each route received echo signals to one of the sixteen lines of a Sum Bus **440**. Two of the sixteen Sum Bus lines are shown at the right side of the drawing, and are coupled to filter circuits **222**. The filtered bus signals are coupled to input pins leading to two second TGC stages **424** and **426**, the gain of which is controlled by the voltage applied to one or two TGC**2** pins. The outputs of these second TGC stages in the illustrated embodiment are connected to output pins leading to channels of the probe's beamformer I.C.

The multiplexer I.C. **18**A also includes a control register **430** which receives control signals over a serial bus from the beamformer I.C. The control register distributes control signals to all of the multiplexers of the multiplexer I.C. as shown by the Ctrl. input arrows.

Constructed embodiments of the multiplexer and beamformer I.C.s will have a number of pins for supply and bias voltages and ground connections and are not shown in the drawings.

It will be appreciated that only a few conductors are needed in the probe cable in the embodiments of FIGS. **2–5** since the numerous conductors for individual transducer elements are replaced by conductors for the beamformer control data, the beamformed output signals and supply voltages for the transducer, beamformer and multiplexer I.C.s. A typical CCD embodiment can require a conductor for the CCD beamformer output signals, a serial data line providing control data from the ultrasound system to the transmit and timing circuitry **300**, DC supply voltages and reference conductors for the beamformer and multiplexer I.C.s, and a drive voltage as required to drive the piezoelectric material during ultrasound transmission. The digital beamformer embodiment would replace the CCD output conductor with a number of conductors equal to the number of bits in a beamformed data word (for parallel transmission) or a serial data line if the beamformed words are being sent to the ultrasound system as serial data. Parallel output data, while requiring more conductors in the cable, affords a worthwhile improvement in axial resolution and eliminates the need for a serial to parallel converter in the ultrasound system.

The circuit board assembly of a thin cable ultrasound probe of the present invention is shown in FIGS. **6***a* and **6***b*. FIGS. **6***a* and **6***b* are side and plan views, respectively, of the inner components of a thin cable ultrasound probe. Two printed circuit boards **82** and **84** are connected in a parallel sandwich arrangement as shown in FIG. **6***a*. The integrated circuits **18** for the multiplexer and for the beamformer **16** are mounted on the printed circuit boards. A transducer array module **12** is mounted at one end of the printed circuit boards and the elements of the array are connected to the multiplexer I.C.s. The number of multiplexer and beamformer I.C.s used will be determined by the number of elements of the transducer array and the desired active aperture during transmission and reception. For example, eight multiplexer I.C.s may be used for a 128 element array when each multiplexer I.C. is capable of connecting to sixteen elements as is the multiplexer I.C. of FIG. **5**. Eight beamformer I.C.s, each with eight receive channels, may be used when a 64 channel receive beamformer is desired. The assembled printed circuit boards and transducer module are connected to a cable as by use of the cable termination technique of U.S. Pat. No. 5,482,047. The finished assembly is mounted in a conventional probe case from which the cable and its connector extend to connect to an ultrasound system.

What is claimed is:

1. A thin cable ultrasonic probe which acquires ultrasonic image information for display, on an ultrasonic diagnostic imaging system, said probe comprising:

a multielement transducer array;

a receive beamformer, coupled to said transducer array, which selectively combines digital echo signals derived from signals received by elements of said transducer array to form digital coherent echo signals; and

a cable, connecting said probe to said ultrasonic diagnostic imaging system, which transmits digital coherent echo signals from said probe to said system.

2. The thin cable ultrasonic probe of claim **1**, further comprising transmit control circuitry coupled to said transducer array to control the transmission of electronically steered and/or focused ultrasound beams by said transducer array,

wherein said cable further includes a conductor for coupling transmit control data from said system to said transmit control circuitry of said probe.

3. The thin cable ultrasonic probe of claim **1**, wherein said cable further includes a conductor for coupling beamformer control data from said system to said receive beamformer of said probe.

4. The thin cable ultrasonic probe of claim **3**, further comprising:

a multiplexer, coupled between said transducer array elements and said beamformer, for coupling signals from selected ones of said transducer array elements to said beamformer,

wherein said beamformer control data includes multiplexer control data.

5. The thin cable ultrasonic probe of claim **1**, wherein said cable further includes a conductor for supplying an energizing potential to electrical components of said probe.

6. A thin cable ultrasonic probe which acquires ultrasonic image information for display on an ultrasonic diagnostic imaging system, said probe comprising:

a multielement transducer array;

transmit circuitry coupled to said array;

a receive beamformer, coupled to said transducer array, which selectively combines echo signals derived from signals received by elements of said transducer array to form coherent analog echo signals, wherein said receive beamformer comprises a CCD beamformer; and

a cable which connects said probe to said ultrasonic diagnostic imaging system, wherein said cable includes a conductor which couples beamformed echo signals from said probe to said system, a data line which couples control data from the ultrasound system to the transmit circuitry, a DC supply voltage conductor coupled to said receive beamformer, a reference potential conductor coupled to said receive beamformer, and a drive voltage conductor, said drive voltage being applied to piezoelectric material of the transducer array under control of said transmit circuitry.

7. The thin cable ultrasonic probe of claim **1**, wherein said receive beamformer comprises a digital beamformer located on an integrated circuit chip, and further comprising:

digital transmit circuitry located on said integrated circuit chip; and

an analog to digital converter located on said integrated circuit chip and having an input coupled to said transducer array and an output coupled to said receive beamformer, and

wherein said cable includes a conductor for coupling digital echo signals from said probe to said system.

8. The thin cable ultrasonic probe of claim **7**, wherein said digital echo signal conductor comprises a serial data line.

9. The thin cable ultrasonic probe of claim **7**, wherein said digital echo signal conductor comprises a plurality of parallel data lines.

10. The thin cable ultrasonic probe of claim **7**, wherein said probe further comprises a digital to analog converter located on said integrated circuit chip.

11. The thin cable ultrasonic probe of claim **1**, further comprising:

transmit control circuitry coupled to control the transmission of electronically steered and/or focused ultrasound beams by said transducer array; and

a multiplexer, coupled between said transmit control circuitry and said transducer array, which couples transmit signals to selected ones of said transducer array elements,

wherein said cable further includes a conductor for coupling transmit control data from said system to said transmit control circuitry of said probe.

12. The thin cable ultrasonic probe of claim **11**, wherein said transmit control data includes multiplexer control data.

13. A thin cable ultrasonic probe which acquires ultrasonic image information for display on an ultrasonic diagnostic imaging system, said probe comprising:

a multielement transducer array;

an integrated circuit including transmit control circuitry coupled to said transducer array which acts to control the transmission of electronically steered and/or focused ultrasound beams by said transducer array, and a receive beamformer, coupled to said transducer array, which acts to selectively combine echo signals received by elements of said transducer array to form at least partially beamformed echo signals; and

a cable which connects said probe to said ultrasonic diagnostic imaging system, including at least one conductor which couples an energizing potential from said ultrasonic diagnostic imaging system to components of said probe, and at least one conductor which couples said at least partially beamformed echo signals to said ultrasonic diagnostic imaging system,

wherein the number of said at least partially beamformed echo signal conductors is less than the number of said elements of said multielement transducer array.

14. The thin cable ultrasonic probe of claim **13**, wherein said cable includes at least one conductor which couples beamformer control signals from said ultrasonic diagnostic imaging system to said probe.

15. The thin cable ultrasonic probe of claim **13**, wherein said beamformer control signals comprise signals for controlling both transmit beamforming and receive beamforming.

16. The thin cable ultrasonic probe of claim **14**, further comprising a multiplexer coupled between said elements of said transducer array and said beamformer for selectively coupling signals received by elements of said transducer array to said beamformer.

17. The thin cable ultrasonic probe of claim **16**, wherein said transmit control circuitry is coupled to said multiplexer to control the transmission of electronically steered and/or focused ultrasound beams by said transducer array,

wherein said cable includes at least one conductor for coupling multiplexer control signals from said ultrasonic diagnostic imaging system to said probe.

18. The thin cable ultrasonic probe of claim **17**, wherein said beamformer control signals comprise signals for controlling both transmit beamforming and receive beamforming.

19. The thin cable ultrasonic probe of claim **13**, wherein said ultrasonic diagnostic imaging system comprises an image processor, responsive to said at least partially beamformed echo signals, which produces ultrasonic image display signals; and a display responsive to said ultrasonic image display signals for displaying an ultrasonic image.

20. The thin cable ultrasonic probe of claim **19**, wherein said image processor further comprises a detector.

21. The thin cable ultrasonic probe of claim **19**, wherein said image processor comprises a processor for producing B mode and Doppler ultrasonic image display signals.

22. The thin cable ultrasonic probe of claim **13**, wherein said image processor comprises a scan converter.

23. The thin cable ultrasonic probe of claim **13**, wherein said integrated circuit further includes an analog to digital converter having an input coupled to said transducer array and an output coupled to said receive beamformer.

24. The thin cable ultrasonic probe of claim **23**, wherein said integrated circuit further includes a digital to analog converter.

25. The thin cable ultrasonic probe of claim **13**, wherein said receive beamformer comprises a sampled data beamformer; and

wherein said cable further comprises a data line which couples control data from said ultrasonic diagnostic imaging system to said transmit control circuitry, a reference potential conductor, and a drive voltage coupled to said transducer array under control of said transmit control circuitry.

26. The thin cable ultrasonic probe of claim **25**, wherein said receive beamformer comprises a digital beamformer.

27. The thin cable ultrasonic probe of claim **25**, wherein said receive beamformer comprises a CCD beamformer.

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