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EUROPEAN PATENT SPECIFICATION

45 Date of publication of patent specification: **16.09.87**

51 Int. Cl.⁴: **G 10 K 11/32, G 10 K 11/30**

21 Application number: **83304222.9**

22 Date of filing: **20.07.83**

54 **Selectable focus ultrasonic transducers for diagnostic imaging.**

30 Priority: **21.07.82 US 400547**
21.07.82 US 400551

43 Date of publication of application:
07.03.84 Bulletin 84/10

45 Publication of the grant of the patent:
16.09.87 Bulletin 87/38

84 Designated Contracting States:
DE FR GB NL

58 References cited:
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US-A-3 903 990
US-A-3 958 559
US-A-4 138 895
US-A-4 276 779

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Description

This invention relates to ultrasonic transducers for diagnostic imaging and, in particular, to transducers of a novel geometric design with reduced sidelobe patterns.

Ultrasonic transducers are used in ultrasonic diagnostic systems to transmit waves of ultrasonic energy into a patient's body. Tissue interfaces in the body reflect some of this energy back toward the transducer in the form of echoes. The echoes are received by the transducer and converted into electrical signals. These signals may be processed by associating them with their times of arrival to reconstruct an image of the tissue or make fluid flow measurements.

In many applications of ultrasound it is desirable to be able to focus the waves or beams of ultrasonic energy at a particular tissue depth. Such focusing permits the reconstruction of images of good lateral resolution at a particular tissue depth of interest, for instance. Focusing may be done in the signal processing, as in the case of phased arrays, or may be provided by the geometric shape of the transducer. Geometric focusing advantageously eliminates much electrical complexity usually required to achieve the same result in the signal processing section of the system. However, geometric focal characteristics are idealized normally for only a single focal point or line of focal points, which restricts the range of good image resolution.

This restriction has been overcome by transducers having selectable geometric focal characteristics. A selectable focus transducer is shown in U.S. Patent 4,138,895. The transducer there shown comprises a disc divided into a center electroded region and an annular electroded region. A user can select just the center electrode for a large depth of focus, or the central and annular regions together for a smaller depth of focus. An acoustic lens provides the transducer arrangement with the desired aperture with point focal characteristics.

Another important characteristic of transducers are sidelobe patterns. Transducers, like antennas, have transmissive characteristics that can be analyzed in terms of main and sidelobes. It is desirable in general to have small sidelobes for an ultrasonic transducer, since large sidelobes can result in the reception and introduction of noise in a reproduced ultrasound image.

It is desirable, then, for an ultrasonic transducer to have good geometric focal characteristics which are adjustable so as to provide good resolution over a range of tissue depths. It is further desirable to reduce the transducer sidelobe patterns so as to minimize noise in the reproduced image.

In accordance with the present invention, an ultrasonic transducer assembly is provided having a novel geometric focal characteristic. The ultrasonic transducer assembly includes a piezoelectric material, the transducer exhibiting an effective radiating surface having a center point.

The assembly is characterized in that said effective radiating surface has an aspheric, semi-conical configuration resembling a concave spherical surface with opposite sides, relative to the center of the surface, canted toward each other. This geometric focal characteristic provides a concentration of ultrasonic energy over a particular range of interest.

In accordance with a preferred embodiment of the present invention, the transducer material is divided into a center disc and an annular ring. When the center disc is activated, the range of optimal focus is located a relatively short distance from the transducer. When both the center disc and annular ring are activated, the range of optimal focus is located at a relatively greater distance from the transducer.

In accordance with a further preferred aspect of the present invention, sidelobes of a transducer of the present invention are reduced by apodization, wherein damping material is located at the outer periphery on the back of the transducer.

In accordance with yet another preferred aspect of the present invention, a proximity switch is provided in the transducer assembly to switch between the long and short focal ranges. In order to prevent the introduction of noise into the received echo signals, the transducer electronics including the switch contacts are surrounded by a continuous shield. In a preferred embodiment of the present invention, the proximity switch comprises a reed switch which is controlled by a magnet located external to the shield. The use of a proximity switch such as a reed switch thus permits the focal ranges to be switched without physically interrupting the shield and hence impairing the noise characteristic of the transducer assembly.

The use of a proximity switch in a dual-aperture ultrasonic probe assembly, but not incorporating the aspheric, semiconical effective radiating surface of the present invention is described and claimed in our copending European patent application No. 86 20 0472.8, which is divided out of the present application.

In the drawings:

FIGURES 1a and 1b illustrate idealized aperture and lobe patterns for a conical surface transducer, known from the prior art;

FIGURES 2a and 2b illustrate idealized aperture and lobe patterns for a spherical surface transducer, known from the prior art;

FIGURES 3a and 3b illustrate idealized aperture and lobe patterns for a transducer constructed in accordance with the present invention;

FIGURES 4, 5, and 6 illustrate different embodiments of transducers constructed in accordance with the present invention;

FIGURES 7a, 7b, and 7c illustrate idealized dual aperture spherical, conical and aspheric transducers; and

FIGURE 8 is an assembly drawing of a transducer probe comprising a transducer in accordance with the present invention.

Referring first to Figure 1a, a conical transducer

is shown in cross-section. The transducer includes a conical surface 12 of piezoelectric ceramic material on a backer 10. The conical transducer exhibits an idealized aperture outlined at 16, which comprises a line of geometric focal points 14 emanating from the center of the transducer. Conical transducers are advantageous in that they exhibit a narrow region of sharply defined focal points. Their disadvantage is that the energy emitted by the conical surface is relatively evenly distributed over the line of focal points. It would be desirable to be able to concentrate the emitted energy in a particular region of the aperture, so as to improve the sensitivity of the transducer at a particular tissue depth of interest.

Figure 2a illustrates a spherical transducer in cross-section. This transducer includes a spherical surface 22 of piezoelectric material mounted on a backer 20. The spherical transducer exhibits an idealized aperture outlined at 26, which contains a single geometric focal point 24. The ultrasonic energy emitted from the spherical surface of the transducer 22 converges at this point, and diverges beyond it. The spherical transducer is capable of producing sharply focused images of tissue in the vicinity of the geometric focal point 24 by reason of the concentrated ultrasonic energy at the point. However, the aperture is only sharply focused at one point, with resolution degrading at regions removed from this point.

A transducer constructed in accordance with the present invention is shown in cross-section in Figure 3a. The transducer there shown is neither conical nor spherical, but exhibits many of the advantages of these two transducer types while overcoming several of their shortcomings. The novel transducer of Figure 3a includes an aspheric surface 32 of piezoelectric material mounted on a backer 30. The shape of the surface 32 is difficult to visualize in three dimensions, but in two dimensional cross-section it resembles a spherical surface transducer which has been bent at the center point 38. The halves of the spherical surface on either side of the center point appear to be folded toward each other. The transducer exhibits the idealized aperture outlined at 36, in which most of the emitted ultrasonic energy is focused at points 34 in an elongated focal region. Unlike the conical and spherical transducers, the ultrasonic energy emitted by the novel transducer is neither focused along the entire center line of the transducer, nor is it focused at a single point. Rather, it is concentrated in an elongated region of optimal focus in which tissue of a significant depth can be imaged with good lateral resolution. The elongated region in a constructed embodiment of the present invention can extend over a six to seven centimeter depth for a 19 mm, 3.5 MHz transducer.

Different embodiments of transducers constructed in accordance with the present invention are shown in Figures 4, 5 and 6. In Figure 4, an aspheric surface piezoelectric element 300 includes a central area 312 which is electrically

separate from an outer annulus 314. The piezoelectric material is mounted in a cylindrical mount 306. The inner area 312 may be activated alone, or a switch 316 may be closed to activate both areas 312 and 314 simultaneously to focus the transducer over different depths of focus. The concave front of the transducer 300 is filled in with an epoxy material to provide a flat face 302 on the transducer.

A preferred embodiment of the present invention is shown in Figure 5. In this embodiment the piezoelectric material exhibits a conical shape, and contains an annular groove which divides the material into an inner conical region 212 and an annular outer region 214. The center region 212 may be activated alone or together with the annular region 214 by closing a switch 216. When the switch 216 is open, the center region 212 will focus in the near field out to a point 218 at approximately 9 centimeters, and when the two regions are activated together, far field focusing is effected out to a point 201 at approximately 14 centimeters.

On the face of the piezoelectric material is an acoustic lens having a spherical face 210. The combination of the conical piezoelectric material 212, 214 and the spherical faced lens provide the aspheric aperture characteristic of the embodiments of Figure 3a and 4. The concave lens is again filled in with epoxy to provide a flat face 208 on the transducer. In a constructed embodiment of Figure 5, the acoustic lens 210 was composed of a high acoustic impedance and velocity epoxy material, and the filler material at 208 was a lower acoustic impedance and velocity epoxy material. The conical piezoelectric transducer 212, 214 and the spherical acoustic lens provide the desired elongated focal region aperture, and the filler 208 forms a simple plano-convex lens which extends the focal zone to point 201. It follows from the principles of this embodiment that an aspheric transducer could also be made utilizing a spherical piezoelectric disc and a conical faced lens.

The embodiment of Figure 5 is more easily manufactured than the other illustrated embodiments of the present invention. This is because a conical ceramic transducer can be readily manufactured and the spherical acoustic lens can be formed by a simple lapping technique. The embodiment of Figure 4, with its aspheric ceramic surface, could be formed by grinding the ceramic material with a precise, numerically controlled lathe, for example.

The embodiment of Figure 6 is composed of a flat disc 400 of piezoelectric material, including a central disc 404 and an annular ring 406, the activation of which is controlled by a switch 416. The disc 400 is fronted with an acoustic lens 402 having an aspheric surface. This combination of piezoelectric material and aspheric lens will produce the same aperture as the embodiments of Figure 4 and 5.

It is desirable for a transducer to exhibit a radiation/reception pattern with reduced sidelobes, since signals received from the sidelobe

regions can introduce noise which will degrade image quality. A conical transducer such as that shown in Figure 1a will exhibit a lobe pattern as shown in Figure 1b, with a large main lobe 40 and sizeable sidelobes 42 and 42'. The large sidelobes 42 and 42' are undesirable in an ultrasonic diagnostic system.

The spherical transducer of Figure 2a will exhibit a more acceptable lobe pattern as shown in Figure 2b. The pattern there shown includes a large main lobe 50 and small sidelobes 52, 52'.

The aspheric transducer of the present invention will exhibit a lobe pattern intermediate those of Figures 1b and 2b. The lobe pattern of a transducer of the present invention is improved in accordance with a further aspect of the present invention by providing backing material around the outer perimeter of the transducer as shown at 304 in Figures 4 and 5. This ring of backing material damps vibrations at the outer perimeter of the piezoelectric material thereby reducing the energy radiated from the perimeter of the piezoelectric material. For the dual focus, two area transducers of Figures 4 and 5, the ring of backing material may be extended to back the central region 212 or 312 to damp vibrations at the perimeter of the central region when it is operated along. This damping technique, generally referred to as apodizing, causes the transducer to be a non-uniform radiator, which "smears" the small side lobes of the transducer as shown in Figure 3b, which illustrates a large main lobe 60 and side lobes 62, 62', which are approximately the same size as the side lobes 52, 52' of the spherical transducer.

A comparison of idealized apertures of different dual focus transducers is shown in Figures 7a, 7b and 7c. Figure 7a illustrates the focal pattern of a simple dual aperture spherical transducer, including a central spherical region 120 and an outer annular region 122. When both regions 120 and 122 of the transducer are activated simultaneously, the transducer exhibits an aperture outlined at 124, which narrows sharply at a focal region 125. Focusing is ineffective beyond the near field limit 129 of the transducer, which is approximately equal to the radius of the transducer squared, divided by the wavelength of operation. The near field limit 129 is thus a linear function of the area of the transducer, which in this case is the total of both regions 120 and 122.

When the spherical transducer is switched to operate in the near field using only the center region 120, the aperture is as outlined by dotted lines 126. This aperture produces a focal region 127 closer to the transducer, with a near field limit at 128 by reason of the reduced area of the transducer. The aperture outlined at 126 does not narrow as sharply as the aperture outlined at 124, however, and the focal region 127 has a greater lateral dimension 1 than focal region 125. This is because the focus is changed by changing the near field limit from 129 to 128; the geometric focus remains the same, generally located slightly beyond the far focal region 125.

Figure 7b illustrates the focal pattern of a simple dual aperture conical transducer having an inner conical surface 130 and an outer annular surface 132. When the inner conical surface 130 is activated alone, the energy from surface 130 focuses along the broken line shown at 137 and bounded by dotted lines 136. When both regions 130 and 132 are activated, the line of focal points is extended to include the points indicated at 135 as well as those at 137, bounded by dashed lines 134. Switching from operation using both regions to operation using only the center region 130 reduces the near field limit, since the transducer area changes, and also reduces the geometric focal length to only the focal points included in aperture outline 136. A line of distributed energy focal points is produced in both cases.

Figure 7c illustrates the focal pattern of a dual focus aspheric transducer of the present invention. When both the central region 140 and the outer annular region 142 of the transducer of Figure 7c are activated, a narrow focal region 145 is produced at the narrow portion of the aperture outlined by dashed lines 144. The area of the full transducer provides a near field limit indicated at 129.

When the transducer of Figure 7c is switched to operation using the central region 140 alone, the area of the transducer is reduced, which moves the near field limit to the line indicated at 128. But the geometric focus of the transducer also changes, since its effective radiating surface is aspheric. Thus the aperture of the central region appears as outlined by dotted lines 146, containing a relatively narrow focal region 147. The focal region 147 is laterally narrower than region 127 of the spherical transducer by reason of the relocation of the geometric focus of the transducer to an area closer to the transducer. Good lateral resolution is therefore provided in both region 145 and region 147.

Since the geometric focus moves closer to the transducer when operation is switched from two region to central region operation, the diameter d' of the central region 140 can be made larger than the diameter d of the equivalent central region 120 of the spherical transducer of Figure 7a. Several benefits result from use of a relatively larger central region. First, a larger region will transmit and receive more energy than a smaller region, thereby increasing the sensitivity of the transducer. Second, with a larger region there is less impedance change when switching from double to single region operation, which makes the tuning electronics coupled to the transducer simpler. And third, a larger central region 140 contributes to the narrowing effect on the aperture 146.

The ultrasonic transducer of the present invention is conveniently mounted in a probe assembly such as that shown in Figure 8. The probe assembly there shown advantageously provides an electrically shielded environment which reduces the tendency to pick up stray electronic interference. The probe assembly also provides a

means for switching the focus of the transducer in a manner which does not interrupt the shielded environment. As the focus of the transducer is switched, the tuning of the transducer is also changed and a signal is provided which indicates the selected focal characteristics.

The probe assembly of Figure 8 includes a forward plastic cylindrical section 150 with a closed acoustic window face 151. The aspheric transducer 152 is located behind the window 151. Leads 156 extend from the separate regions of the transducer. The interior of the cylindrical section 150 is lined with a nonmagnetic shield 154 such as copper. The rear portion of the cylindrical section 150 narrows to a smaller diameter as indicated by dividing ridge 157. Two dimples shown at 158 are provided on the outside of the narrow portion which form a portion of the detent mechanism of the switch. The end 159 of the cylindrical section 150 is open.

A plastic ring 160 slides over the narrow portion of the cylindrical section 150 up to the ridge 157. On the inner surface of the ring 160 is a small ball 162 which rides between the dimples 158 and snaps into them to provide a detent mechanism for the ring. A groove 168 is formed around the inner surface of the ring to hold a magnet 164 in a predetermined position relative to the ball bearing 162. A small pin 166 extends from the inner surface of the ring at the bottom of the ring.

With the ring 160 in place on the forward cylindrical section 150, a rear cylindrical section 170 slides over the remainder of the narrow portion of section 150. A recessed collar 176 is then located under the ring 160. The collar 176 has a slot 174 in it so that pin 166 can move from one end of the slot to the other as the ring 160 is turned. The pin and slot thereby provide a stop for the ring to permit the ring to be turned only through the arc of the slot.

Finally, the wires 156 from the transducer are soldered to a small printed circuit board 190, mounted on an r.f. connector 180. The r.f. connector 180 is inserted into the open end 159 of the section 150 up to the lip 181 of the connector. Mounted on the connector at a plastic ring 183 are three reed switches 184, 186 and 188. The reed switches are wired to the printed circuit board 190. When the connector is inserted in the section 150 in the proper position, the reed switches are located under either side of the arc traversed by the magnet 164 as the ring 160 is turned. When the ring is turned to one detent position the magnet 164 is located over reed switches 184 and 186 to close them. And when the ring is in its other detent position the magnet is located over reed switch 188 to close it. The r.f. connector 180 and copper shield 154 provide a completely shielded cavity for the wiring, printed circuit board, switches, and board components in the inside of the section 150.

Turning the ring performs three switching functions in the probe assembly. First, the focal characteristics of the transducer are switched between short focus using only the central disc of

the transducer, and long focus by connecting the central disc and annular ring of the transducer together to be activated simultaneously. Second, the tuning of the circuitry on circuit board 190 is switched to match the respective electrical characteristics of the transducer in the two operating modes. Third, a resistance value on the circuit board is changed to produce a signal indicative of the operating mode, which signal is coupled out through the connector along with signals to and from the transducer.

Claims

1. An ultrasonic transducer assembly including a piezoelectric material, the transducer exhibiting an effective radiating surface (32) having a center point (38) characterised in that said effective radiating surface (32) has an aspheric, semi-conical configuration resembling a concave spherical surface with opposite sides relative to the center of the surface canted towards each other.

2. The transducer assembly of claim 1, wherein the piezo-electric material (300) has the aspheric, semi-conical configuration.

3. The transducer assembly of claim 1, wherein the effective radiating surface is provided by use of a conical piece of piezo-electric material (212, 214) and an acoustic lens (210) affixed to said conical surface and having a spherical surface remote from said conical surface.

4. The transducer assembly of claim 1, wherein the effective radiating surface is provided by use of a flat disc of piezo-electric material (400) having a front face and an acoustic lens (402) mounted on said front face, the lens having the aspheric semiconical configuration on its surface remote from said flat disc (400).

5. The transducer assembly of claim 3 or claim 4, wherein the acoustic lens (210 or 402) comprises epoxy exhibiting a high acoustic impedance and velocity relative to human tissue.

6. The transducer assembly of any one of claims 1 to 5, wherein said piezo-electric material comprises a central member (212, 312, 404) having an outer perimeter symmetrically disposed with respect to said center point, and an annular member (214, 314, 406) electrically separated from and symmetrically disposed about the perimeter of said central member.

7. The transducer assembly of claim 6, wherein said central member (140) exhibits a first geometric focus (147) and near field focus limit (128), and said central member (140) and said annular member (142) together exhibit a second geometric focus (145) and near field focus limit (129).

8. The transducer assembly of any one of claims 1 to 7, further comprising an annulus (304) of backing material affixed to the back of the piezo-electric material around the outer perimeter thereof.

9. An ultrasonic transducer probe comprising: a housing (150, 160, 170) having an electrically shielded interior space having a transducer

assembly according to claim 6 or any claim dependent thereon located at one end thereof;

means (180), located in a wall of said housing, for making electrical connection between said interior space and the exterior of said housing;

a reed switch (184), located in said shielded interior space and connected to said central and annular members and said electrical connection means (180) for selectively coupling said members to said connection means; and

a magnet (164) located external to said shielded interior space and movably mounted so as selectively to open and close said reed switch (184) for varying the coupling of said central and annular members to said electrical connection means (180).

10. The probe of claim 9, wherein said reed switch (184) has a first terminal coupled to said central member and a second terminal connected to said annular member, and the electrical connection means comprises an r.f. connector (180) having a conductor connected to said first reed switch terminal.

11. The probe of claim 10, further comprising a tuned circuit (190) located in said shielded interior space and a second reed switch (186) located in said shielded interior space in close proximity to said external magnet (164) and connected to said piezo-electric material and said tuned circuit (190) for selectively coupling said tuned circuit (190) to said piezo-electric material.

Patentansprüche

1. Ultraschallwandler, umfassend ein piezoelektrisches Material, wobei der Wandler eine wirksame strahlende Oberfläche (32) mit einem Mittelpunkt (38) aufweist, dadurch gekennzeichnet, daß die wirksame strahlende Oberfläche (32) eine asphärische, halbkonische Konfiguration aufweist, die einer konkaven sphärischen Oberfläche, wobei die gegenüberliegenden Seiten in bezug auf die Mitte der Oberfläche gegeneinander abschrägt sind.

2. Ultraschallwandler nach Anspruch 1, worin das piezoelektrische Material (300) die asphärische, halbkonische Konfiguration aufweist.

3. Ultraschallwandler nach Anspruch 1, worin die wirksame strahlende Oberfläche durch Verwendung eines konischen Teils aus piezoelektrischem Material (212, 214) und einer akustischen Linse (210) vorgesehen ist, die an der konischen Oberfläche befestigt ist und eine sphärische Oberfläche entfernt von der konischen Oberfläche aufweist.

4. Ultraschallwandler nach Anspruch 1, worin die wirksame strahlende Oberfläche unter Verwendung einer flachen Scheibe aus piezoelektrischem Material (400) mit einer Vorderseite und einer akustischen Linse (402) vorgesehen ist, die an der Vorderseite angebracht ist, wobei die Linse die asphärische halbkonische Konfiguration an ihrer von der flachen Scheibe (400) entfernten Oberfläche aufweist.

5. Ultraschallwandler nach Anspruch 3 oder

Anspruch 4, worin die akustische Linse (210 oder 402) aus Epoxyharz besteht, das in bezug auf menschliches Gewebe eine hohe akustische Impedanz und Geschwindigkeit aufweist.

6. Ultraschallwandler nach einem der Ansprüche 1 bis 5, worin das piezoelektrische Material ein mittleres Organ (212, 312, 404) mit einem Außendurchmesser umfaßt, der in bezug auf den Mittelpunkt symmetrisch angeordnet ist, sowie einem ringförmigen Organ (214, 314, 406), das von dem mittleren Organ elektrisch getrennt und um den Umfang des mittleren Organs symmetrisch angeordnet ist.

7. Ultraschallwandler nach Anspruch 6, worin das mittlere Organ (140) einen ersten geometrischen Mittelpunkt (147) und eine nahe Feldmittelpunktbegrenzung (128) aufweist und das mittlere Organ (140) sowie das ringförmige Organ (142) zusammen einen zweiten geometrischen Mittelpunkt (145) und eine nahe Feldmittelpunktgrenze (129) aufweisen.

8. Ultraschallwandler nach einem der Ansprüche 1 bis 7, bestehend ferner aus einem Ring (304) aus abstützendem Werkstoff, der an der Rückseite des piezoelektrischen Materials rund um dessen Umfang befestigt ist.

9. Ultraschallwandlermeßkopf, bestehend aus: einem Gehäuse (150, 160, 170) mit einem elektrisch abgeschirmten Innenraum mit einem Ultraschallwandler gemäß Anspruch 6 oder irgend einem von diesem abhängigen Anspruch, der an einem Ende desselben angeordnet ist;

Mitteln (180), die in einer Wand des Gehäuses zur Herstellung einer elektrischen Verbindung zwischen dem Innenraum und dem Äußeren des Gehäuses angeordnet sind;

ein Reed-Schalter (184), der in dem abgeschirmten Innenraum angeordnet ist und mit dem genannten mittleren und ringförmigen Organ sowie den elektrischen Verbindungsmitteln (180) für die selektive Kupplung der Organe mit den Verbindungsmitteln verbunden ist; und

einem Magneten (164), der außerhalb des abgeschirmten Innenraums angeordnet sowie beweglich befestigt ist, um den Reed-Schalter (184) zur Veränderung der Kupplung der zentralen und ringförmigen Organe mit den elektrischen Verbindungsmitteln (80) wahlweise zu öffnen und zu schließen.

10. Meßkopf nach Anspruch 9, worin der Reed-Schalter (184) eine erste Klemme aufweist, die an das mittlere Organ gekoppelt ist, sowie eine zweite Klemme, die mit dem ringförmigen Organ verbunden ist, und daß die elektrischen Verbindungsmittel eine r.f. Steckverbindung (180) mit einem Stecker umfassen, der mit der Klemme des ersten Reed-Schalters verbunden ist.

11. Sonde nach Anspruch 10, bestehend aus einem abgestimmten Kreis (190), der in dem abgeschirmten Innenraum angeordnet ist, sowie einem zweiten Reed-Schalter (186), der in dem abgeschirmten Innenraum in unmittelbarer Nähe zu dem äußeren Magneten (164) angeordnet und an das piezoelektrische Material sowie den abgestimmten Kreis (190) zur wahlweisen Kopplung

des abgestimmten Kreises (190) an das piezo-elektrische Material angeschlossen ist.

Revendications

1. Transducteur ultrasonore comprenant un matériau piézo-électrique, le transducteur présentant une surface active rayonnante (32) ayant un point central (38), caractérisé en ce que la surface active rayonnante (32) a une configuration non sphérique semiconique ressemblant à une surface sphéroconcave dont les bords opposés par rapport au centre de la surface sont inclinés l'un vers l'autre.

2. Transducteur selon la revendication 1 dans lequel le matériau piézo-électrique (300) présente la configuration asphérique semiconique.

3. Transducteur selon la revendication 1, dans lequel la surface active rayonnante est formée par utilisation d'une pièce conique de matériau piézo-électrique (212, 214) et une lentille acoustique (210) fixée à la surface conique et présentant une surface sphérique éloignée de la surface conique.

4. Transducteur selon la revendication 1, dans lequel la surface active rayonnante est formée par utilisation d'un disque plat de matériau piézo-électrique (400) ayant une face avant et une lentille acoustique (402) montée sur cette face avant, la lentille présentant la configuration asphérique semiconique sur sa surface opposée au disque plat (400).

5. Transducteur selon l'une des revendications 3 ou 4, dans lequel la lentille acoustique (210 ou 402) comprend une résine époxy présentant une impédance et une vitesse acoustique élevées par rapport à un tissu humain.

6. Transducteur selon l'une quelconque des revendications 1 à 5, dans lequel le matériau piézo-électrique comprend un élément central (212, 312, 404) ayant un périmètre externe disposé de façon symétrique par rapport à son point central, et un élément annulaire (214, 314, 406) séparé électriquement du périmètre de cet élément central et disposé symétriquement autour de celui-ci.

7. Transducteur selon la revendication 6, dans lequel l'élément central (140) présente un premier foyer géométrique (147) et une limite focale en

champ proche (128), et en ce que l'élément central (140) et l'élément annulaire (142) pris ensemble présentent un second foyer géométrique (145) et une seconde limite focale en champ proche (129).

8. Transducteur selon l'une quelconque des revendications 1 à 7, comprenant en outre un anneau (304) de matériau d'appui fixé au dos du matériau piézo-électrique autour de son périmètre externe.

9. Sonde de transducteur ultrasonore comprenant:

un boîtier (150, 160, 170) ayant un espace intérieur blindé électriquement comprenant un transducteur selon la revendication 6 ou l'une quelconque des revendications qui en dépendent situé à ses extrémités;

des moyens (180) disposés dans une paroi du boîtier pour effectuer une connexion électrique entre l'espace intérieur et l'extérieur de ce boîtier;

un commutateur à lame (184) disposé dans l'espace intérieur blindé et connecté aux éléments central et annulaire et aux moyens de connexion électrique (180) pour coupler sélectivement lesdits éléments aux moyens de connexion;

un aimant (164) situé à l'extérieur de l'espace interne blindé et monté de façon mobile de façon à ouvrir et fermer sélectivement le commutateur à lame (184) pour faire varier le couplage des éléments central et annulaire avec les moyens de connexion électrique (180).

10. Sonde selon la revendication 9, dans laquelle le commutateur à lame (184) comprend une première borne couplée à l'élément central et une seconde borne connectée à l'élément annulaire, et dans laquelle les moyens de connexion électrique comprennent un connecteur r.f. (180) muni d'un conducteur connecté à la première borne du commutateur à lame.

11. Sonde selon la revendication 10, caractérisée en ce qu'elle comprend en outre un circuit accordé (190) situé dans l'espace intérieur blindé et un second commutateur à lame (186) disposé dans l'espace intérieur blindé à proximité étroite de l'aimant externe (164) et connecté au matériau piézo-électrique et au circuit accordé (190) pour coupler sélectivement le circuit accordé (190) au matériau piézo-électrique.

FIG-1a

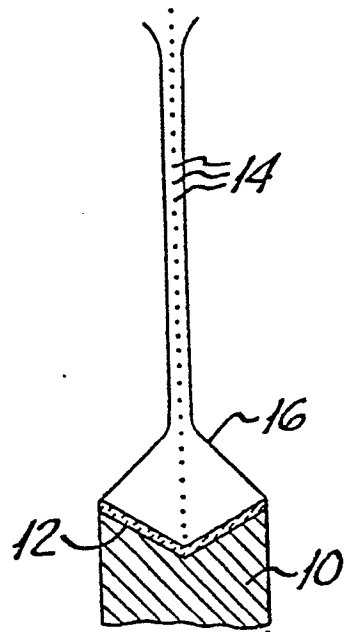


FIG-1b

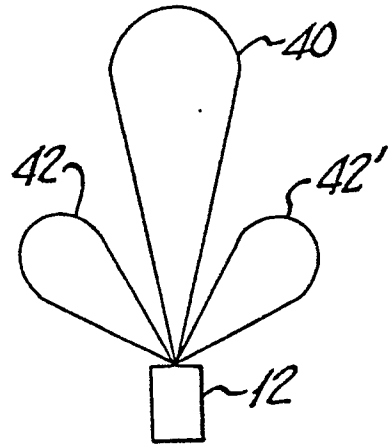


FIG-2a

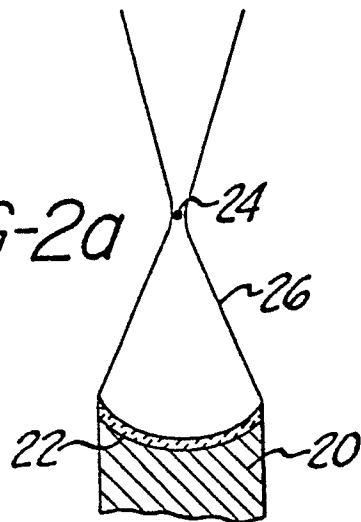


FIG-2b

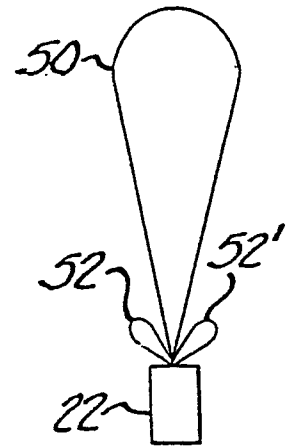


FIG-3a

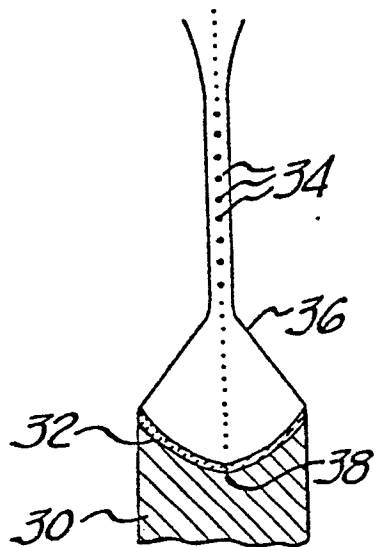


FIG-3b

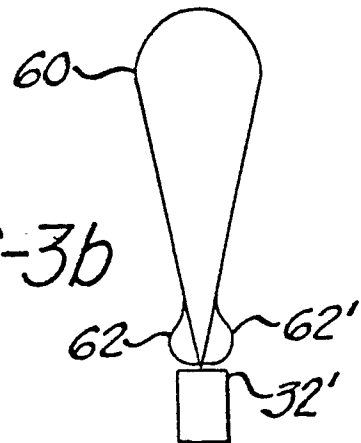


FIG-4

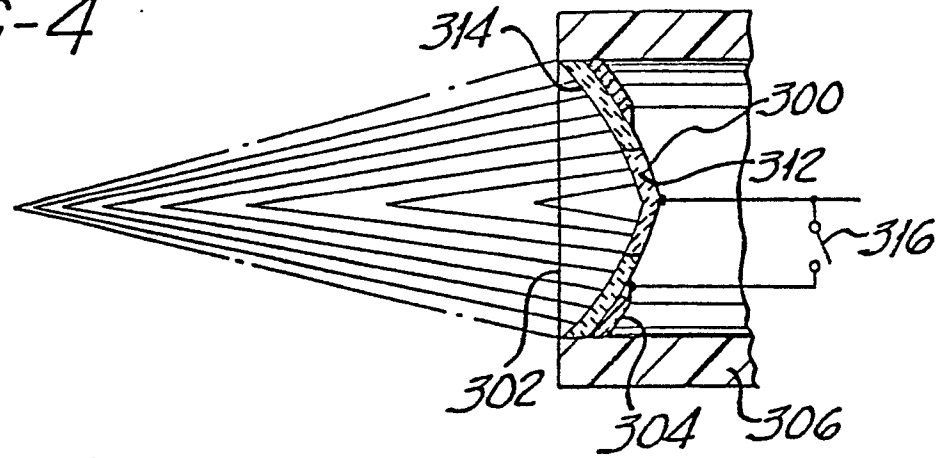


FIG-5

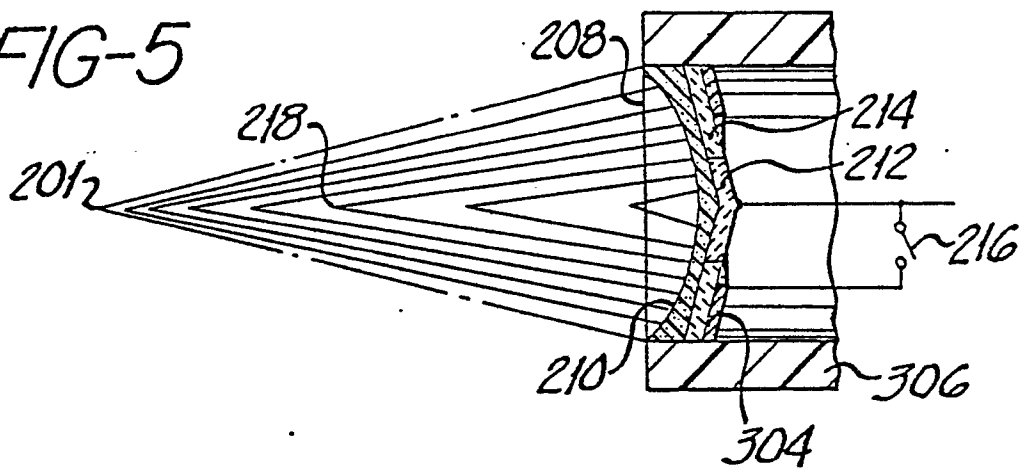
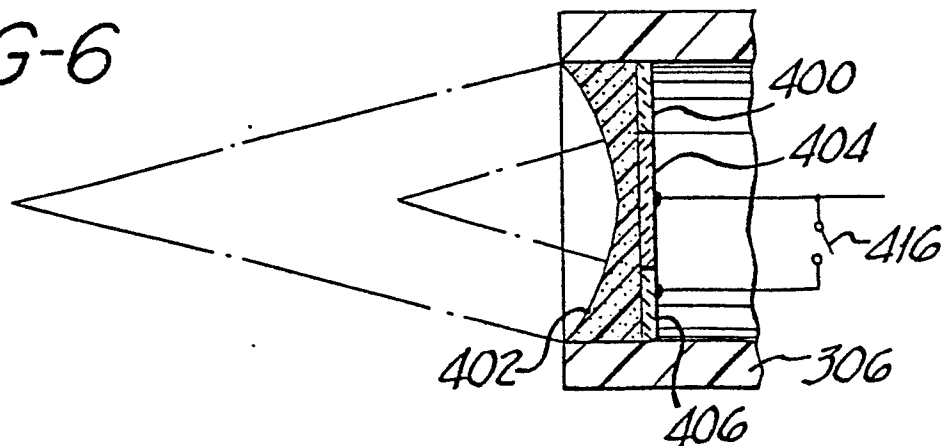


FIG-6



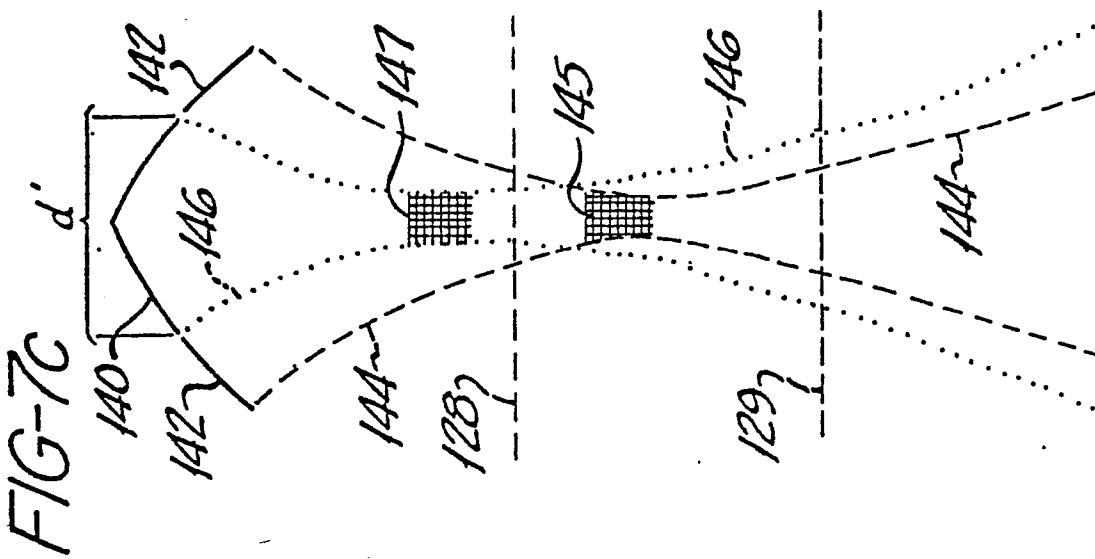
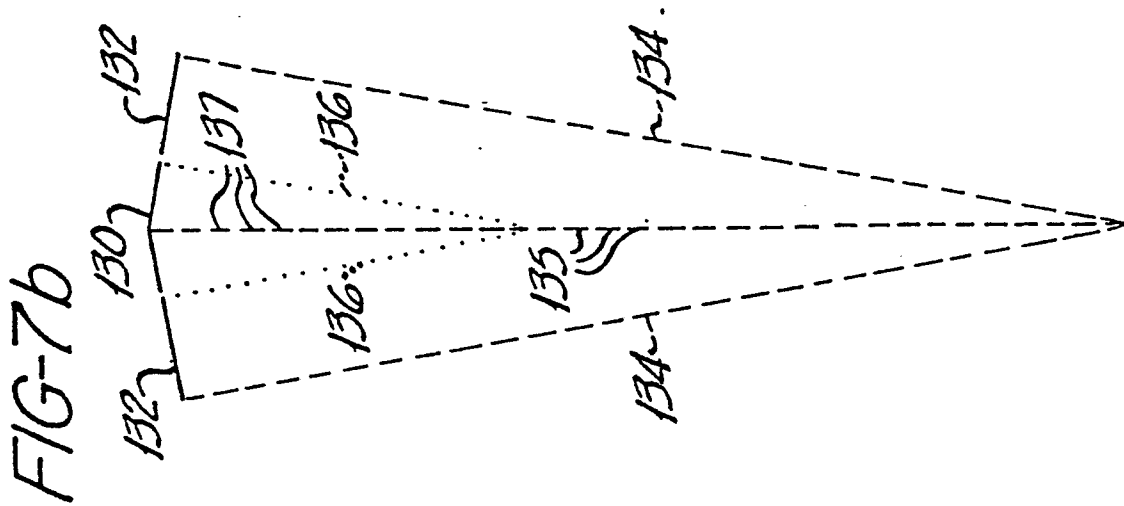
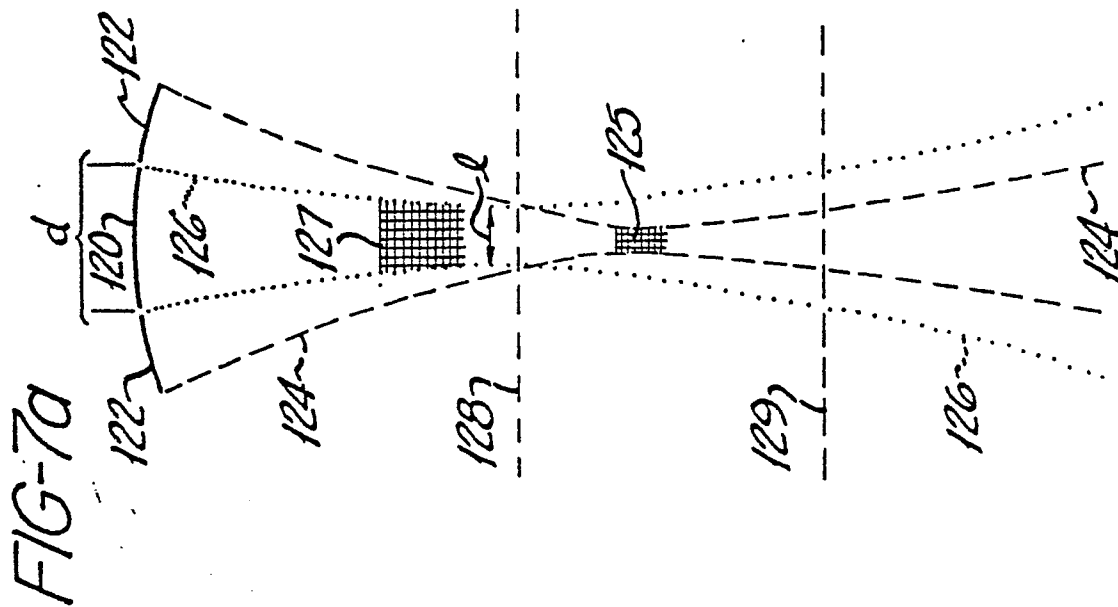


FIG-8

