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(54) **SYSTEMS FOR REDUCING SECONDARY HOT SPOTS IN A PHASED ARRAY FOCUSED ULTRASOUND SYSTEM**

SYSTEME ZUR VERMINDERUNG SEKUNDÄRER HEISSER STELLEN IN PHASENGESTEUERTEN FOKUSIERTEN ULTRASCHALLSYSTEMEN

SYSTEMES DE REDUCTION DES ZONES SENSIBLES SECONDAIRES DANS UN SYSTEME A ULTRASONS FOCALISE A RESEAU EN PHASE

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Description

FIELD OF THE INVENTION

[0001] The present invention relates generally to systems for performing noninvasive surgical procedures using focused ultrasound, and more particularly to systems for reducing secondary hot spots created by a focused ultrasound transducer array.

BACKGROUND

[0002] High intensity focused acoustic waves, such as ultrasonic waves (acoustic waves with a frequency greater than about 20 kilohertz), may be used to therapeutically treat internal tissue regions within a patient. For example, ultrasonic waves may be used to ablate tumors, thereby obviating the need for invasive surgery. For this purpose, piezoelectric transducers driven by electric signals to produce ultrasonic energy have been suggested that may be placed external to the patient but in close proximity to the tissue to be ablated. The transducer is geometrically shaped and positioned such that the ultrasonic energy is focused at a "focal zone" corresponding to a target tissue region within the patient, heating the target tissue region until the tissue is necrosed. The transducer may be sequentially focused and activated at a number of focal zones in close proximity to one another. This series of sonications is used to cause coagulation necrosis of an entire tissue structure, such as a tumor, of a desired size and shape.

[0003] A spherical cap transducer array, such as that disclosed in U.S. Patent No. 4,865,042 issued to Umemura et al., has been suggested for this purpose. This spherical cap transducer array includes a plurality of concentric rings disposed on a curved surface having a radius of curvature defining a portion of a sphere. The concentric rings generally have equal surface areas and may also be divided circumferentially into a plurality of curved transducer elements or sectors, creating a sector-vortex array. The transducer elements are driven by radio frequency (RF) electrical signals at a single frequency offset in phase and amplitude. In particular, the phase and amplitude of the respective drive signals may be controlled so as to focus the emitted ultrasonic energy at a desired "focal distance," i.e., the distance from the transducer to the center of the focal zone and provide a desired energy level in the target tissue region.

[0004] Although the transducer elements are focused at a desired primary focal zone, there may also be one or more secondary focal zones at locations other than the intended primary focal zone. For example, spaces between the concentric rings may contribute to such "hot spots," particularly in the "near field," i.e., the region between the transducer and the primary focal zone. Such secondary hot spots may lead to undesired heating, pain for the patient, and/or possibly necrosis of tissue in the near field. Because the transducer is made up of a finite number of rings, the step function used to change the phase between the rings may also contribute to the creation of secondary hot spots.

[0005] To minimize the effects of secondary hot spots, one proposed solution has been to use a wide-band frequency signal to drive the transducer elements, such that the location of the secondary hot spots may be "smeared" by this wide-band signal, i.e., the energy diffused within tissue regions at different locations within the patient, thereby reducing the risk of heating the tissue regions sufficiently to necrose them. This solution, however, may be limited by the transducer bandwidth and may require special complicated electronics. Wide-band drive signals may also smear the primary focal zone, thereby requiring increased ultrasonic energy delivery to ablate the target tissue at the primary focal zone. The smearing of the primary focal zone may be at least partially corrected by introducing appropriate delays in the signals, but this may substantially complicate control of the phased array, for example, requiring additional electronic phasing and focusing.

[0006] in WO-A-99 40847, there is described a system for performing a therapeutic procedure in a target tissue region of a patient using focused ultrasound within a primary focal zone according to the preamble of claims 1 and 9. Specifically, WO-A-99 40847 discloses such a system compiling an array of transducer elements, and drive circuitry coupled to the transducer elements, the drive circuitry configured to provide respective drive signals to the transducer elements at, at least, first and second discrete frequencies.

[0007] Accordingly, it would be desirable to provide systems and methods for treating a tissue region using ultrasound energy at one or several discrete frequencies that reduces secondary hot spots, without substantially reducing the intensity at the primary focal zone.

[0008] The object of the present invention is to provide a system for performing a therapeutic procedure using focused ultrasound that substantially minimizes the effects of secondary hot spots, without adversely impacting on the energy delivered to the primary focal zone.

[0009] To achieve this, the system of the invention is characterized by the features claimed in the characterizing part of claim 1 or 9.

[0010] According to the invention, the system further comprises a controller coupled to the drive circuitry, the controller configured for periodically changing the frequency of the respective drive signals provided by the drive circuitry between at least the first and second frequencies as often as every 0.2-0.5 seconds while substantially maintaining focus at the primary focal zone during a single sonication.

[0011] In a preferred embodiment, a focused ultrasound system includes a transducer formed from piezoelectric material that includes a plurality of transducer elements. The transducer elements may be provided in a variety of arrays or geometries. For example, in one exemplary embodiment, the transducer may be a substantially concave phased array, including a plurality of concentric rings. Each transducer ring may be divided circumferentially into a plurality of curved elements or "sectors." Alternatively, a linear array of transducer elements may be provided. Other arrangements or geometries of transducer elements may also be provided, such as a checkerboard pattern, a hexagonal lattice, or a random pattern of transducer elements, and the invention should not be limited to any one particular geometry.

[0012] Drive circuitry is coupled to each of the respective transducer elements for providing drive signals to each transducer element at one of a plurality of discrete frequencies, preferably at radio frequencies. A controller is coupled to the drive circuitry for periodically changing a frequency of the drive signals during a single sonication between one of the plurality of discrete frequencies. In particular, the controller determines a phase component for each of the respective drive signals provided, such that a primary focal zone of a given size and shape results at a predetermined distance from the transducer.

[0013] The transducer is preferably adjustably mounted within a casing, such as a fluid-filled table, onto which a patient may be disposed. During use of the system, the plurality of transducer elements may be activated with a set of drive signals, each at a single frequency, while focusing ultrasonic energy produced by the transducer elements at the primary focal zone, corresponding to the location of a target tissue region in a patient. Periodically, the frequency of the respective drive signals may be changed, while substantially maintaining the focus at the primary focal zone. Preferably, this is achieved by controlling the phase component of the drive signals when the frequency of the drive signals is changed.

[0014] The series of drive signals is provided to the transducer to create a single sonication that substantially ablates the tissue at the target tissue region, while minimizing the effects of secondary focal zones or "hot spots." As the frequency is changed, the location of the secondary hot spots may change, thereby dispersing the ultrasonic energy at the secondary hot spots to several locations within the patient's body. Thus, while the target tissue region receives sufficient energy to substantially necrose the tissue there, the tissues at the secondary hot spots do not.

[0015] Other objects and features of the present invention will become apparent from consideration of the following description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Preferred embodiments of the present invention are illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings, in which like reference numerals refer to like components, and in which:

FIG. 1A is a schematic diagram of one embodiment of a focused ultrasound system, in accordance with the present invention.

FIG. 1B is a top view of the transducer array of the focused ultrasound system of FIG. 1A.

FIG. 2 is a schematic side view of a patient on a water-filled table having an ultrasound transducer array therein.

FIG. 3 is a graph showing the locations of secondary hot spots for various frequency signals used to drive an ultrasound transducer focused at a fixed primary focal zone.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0017] Turning now to the drawings, FIGS. 1A, 1B, and 2 show a preferred embodiment of a system 10 for performing a therapeutic procedure using focused ultrasound, in accordance with the present invention. The system 10 generally includes a transducer 12, drive circuitry 14 for providing electrical drive signals 15 to the transducer 12, and a controller 16 for controlling the drive signals 15 provided by the drive circuitry 14. The transducer 12 is preferably a phased array ultrasound transducer formed from piezoelectric material, constructed as is known to those skilled in the art.

[0018] In one preferred embodiment, shown in FIGS. 1A and 1B, the transducer 12 may have a concave or bowl shape, such as a "spherical cap" shape, i.e., having a substantially constant radius of curvature 18 such that the transducer 12 has an inside surface 20 defining a portion of a sphere. The transducer 12 may be divided into a plurality of concentric rings 22-1 to 22-n (where n is the total number of rings), for example, by cutting concentric circles through a piezoelectric shell (not shown). Preferably, each of the rings 22-1 to 22-n has substantially the same surface area, and thus, the widths of the rings 22 are progressively smaller from the innermost ring 22-1 outward to the outermost ring 22-n. Alternatively, the rings 22 may have equal widths (not shown), such that the area of each ring 22 is progressively larger from the innermost ring to the outermost ring. Any spaces (not shown) between the rings 22 may be filled with silicone rubber and the like to substantially isolate the rings 22 from one another. Each ring 22 may also be divided circumferentially into curved elements or "sectors" 23 (23-1a to 23-1h are illustratively shown for the innermost ring 22-1 in FIG. 1B), for example, by removing thin radial strips of electrode (not shown) from the back of the transducer 12 between each sector 23. In a preferred embodiment, the transducer 12 has an outer diameter of between about 8-12 cm, a radius of curvature 18 between about 8-16 cm, and includes between about ten and thirty rings 22, each of which is divided into 4-16 sectors 23.

[0019] Additional information on the construction of a phased array transducer appropriate for use with the present invention may be found, for example, in T.Fjield and K. Hynynen, "The Combined Concentric-Ring and

Sector-Vortex Phased Array for MRI Guided Ultrasound Surgery," IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 44, no. 5, pages 1157-1167 (Sept 1997). Alternatively, a concentric-ring transducer may be provided that is not divided into circumferential sectors (not shown). Such a concentric-ring transducer is shown, for example, in C. Cain and S. Umemura, "Concentric-Ring and Sector-Vortex Phased-Array Applicators for Ultrasound Hyperthermia," Transactions on Microwave Theory and Techniques, vol. MTT-34, no. 5, pages 542-551 (May 1986).

[0020] In another preferred embodiment (not shown), a linear array of transducer elements may be provided that may be focused at a primary focal zone having a desired shape, such as a linear focal zone. Alternatively, other arrangements or geometries of transducer elements may be provided, such as a checkerboard pattern or a hexagonal lattice. The transducer elements may be provided on a curved, spherical cap transducer, a substantially flat transducer, and the like, that may be focused at a primary focal zone.

[0021] Returning to FIG. 1B, each of the sectors 23 of the rings 22 is individually coupled to the drive circuitry 14 in a conventional manner. The drive circuitry 14 is configured to provide electrical drive signals 15 to the sectors 23 at a plurality of discrete frequencies, preferably at radio frequencies (RF), for example, between about 0.5-10 MHz, and more preferably between about 1.0 and 2.0 MHz. When electrical drive signals 15 are provided to the sectors 23, the transducer 12 emits ultrasonic energy from its inside surface 20, as is known to those skilled in the art.

[0022] The controller 16 is coupled to the drive circuitry 14 for controlling several aspects of the drive signals 15 generated by the drive circuitry 14, such as the frequency, phase, and amplitude. First, the controller 16 may control the amplitude of the drive signals 15, for example, to control the intensity of ultrasonic energy delivered by the transducer 12. In addition, the controller 16 may control the phase between each of the concentric rings 22 and between each of the sectors 23. By shifting the phase between the concentric rings 22, a "focal distance," i,e., the distance from the transducer 12 to the center of the focal zone, may be adjusted along the z axis, as is know to those skilled in the art.

[0023] Shifting the phase between the sectors 23 allows control of the size and shape of the focal zone of the ultrasonic energy, or "mode" of the transducer 12, as is also known to those skilled in the art. Further information on phase shifting of phased array transducers may be found in the Fjield and Cain articles referenced above, as well as in U.S. Patent No. 4,865,042 issued to Umemura et al..

[0024] The controller 16 also preferably controls the frequency of the drive signals 15 provided to the transducer 12. The drive signals 15 supplied to the transducer 12 at one time are all preferably provided at the same discrete frequency. During a single sonication, which may have a duration of between about 5-20 seconds, and more preferably about 10 seconds or more, the controller 16 periodically changes the frequency of the drive signals 15 as often as every 0.2-0-5 seconds. At the same time, the controller 16 controls the phase and/or amplitude of the drive signals 15 to maintain the focal zone of the resulting ultrasonic energy generated by the transducer 12 at a desired region within a patient's body. Thus, the controller 16 may direct the drive circuitry to provide a plurality of sequential sets of drive signals 15, each set being at a discrete frequency different from the previous set.

[0025] As shown in FIG. 2, the transducer 12 is preferably mounted within a fluid-filled casing, such as table 30. The table 30 includes a chamber 32 filled with degassed water or similar acoustically transmitting fluid. The transducer 12 is preferably connected to a positioning system 34 that moves the transducer 12 within the chamber 32 and consequently mechanically adjusts the focal zone 38 of the transducer 12. For example, the positioning system 34 may be configured to move the transducer 12 within the chamber 32 in any one of three orthogonal directions, e.g., horizontally forward and backward, horizontally side-to-side, and vertically. U.S. Patent Nos. 5,247,935 issued to Cline et al. and 5,275,165 issued to Ettinger et al., disclose exemplary positioning systems that may be used.

[0026] Alternatively, the positioning system 34 may simply pivot the transducer 12 about a fixed point within the chamber 45, i.e., to change the angle of the transducer 12 and consequently the focal zone 38 with respect to a horizontal plane (not shown). In this alternative, the focal distance of the transducer 12 may be controlled electronically by changing the phase and/or amplitude of the drive signals 15 provided to the transducer 12, as described above. In further alternatives, the positioning system 34 may move the transducer 12 in a horizontal plane perpendicular to the line of propagation (not shown), with the depth controlled electronically, or other combinations of mechanical and electronic positioning may be used.

[0027] The top of the table 30 includes a flexible membrane 36 that is substantially transparent to ultrasound, such as a mylar plastic or polyvinyl chloride (PVC) sheet. A fluid-filled bag or cushion is generally provided along the top of the table that may conform easily to the contours of a patient placed on the table. In a further alternative, the transducer 10 may be mounted in a fluid-filled bag mounted on a movable arm (not shown) that may be placed in contact with a patient, such as that disclosed in U.S. Patent No. 5,526,814.

[0028] In addition, the system 10 may include an imaging device (not shown) for monitoring the use of the system during treatment of a patient For example, the system 10 may be placed within a magnetic resonance imaging (MRI) device, such as that disclosed in U.S. Patent Nos. 5,247,935, 5,291,890, 5,368,031, 5,368,032, 5,443,068 issued to Cline et al., and U.S. Patent Nos.

5,307,812, 5,323,779, 5,327,884 issued to Hardy et al.

[0029] Returning to FIG. 2, during use, a patient 40 may be disposed on the table 30 with water, ultrasonic conducting gel, and the like applied between the patient 30 and the bag or membrane 36, thereby acoustically coupling the patient 30 to the transducer 12. The transducer 12 may be focused towards a target tissue region within a tissue structure 42, which may, for example, be a cancerous or benign tumor. The transducer 12 may be activated by supplying a set of drive signals 15 at a discrete frequency to the transducer 12 to focus ultrasonic energy at the target tissue region 42. During the course of the sonication, the frequency of the drive signals 15 may be changed periodically, as described above, while maintaining the focus at the target tissue region 42. The transducer 12 may be activated for sufficient time to substantially necrose the target tissue region 42, e.g., between about 5-20 seconds, and more preferably about 10 seconds or more.

[0030] The transducer 12 may be deactivated, for example, for sufficient time to allow heat absorbed by the patient's tissue to dissipate, e.g., between about 45-90 seconds, and more preferably about 60 seconds or more. The transducer 12 may then be focused on another target tissue region (not shown), for example, adjacent to the target tissue region 42, and the process repeated until the entire target tissue structure is ablated.

[0031] A system in accordance with the present invention uses control of the frequency of the drive signals, preferably during a single substantially continuous sonication, to reduce the effects of secondary hot spots. Because the locations of both primary and secondary focal zones vary depending upon the frequency of the drive signals, different frequency drive signals may cause the focal zones or "hot spots" created by the transducer to move to different locations or focal distances within the patient as the frequency is changed. The controller of a system according to the present invention changes the frequency, but substantially maintains the primary focal zone of the ultrasonic energy at a target region within a patient's body by simultaneously adjusting the phase and/or amplitude of the drive signals provided to the transducer elements. The secondary hot spots, however, do not remain at the same locations, but become focused at different locations as the frequency is changed.

[0032] This is illustrated, for example, in FIG. 3, which shows the energy intensity (in W/m^2) produced by a transducer in relation to the distance (z) from the transducer. In this example, the transducer is focused at a focal distance of about 150 mm, while the frequency of the drive signals is changed from 1.3 MHz, to 1.5 MHz, to 1.7 MHz. As may be seen from the three corresponding curves, the distances from the transducer of the secondary hot spots shift from about 55 mm at 1.3 MHz, to about 60 mm at 1.5 MHz, to about 65 mm at 1.7 MHz. Thus, the energy delivered at the secondary hot spots is absorbed by different tissue regions as the frequency changes. This diffuses the energy, substantially minimizing the risk of heating tissue at the secondary hot spots to an intensity level sufficient to cause pain, or damage or necrose the tissue. Because the primary focal zone remains substantially constant at a fixed focal distance, the tissue at the primary focal zone may be heated sufficiently to achieve necrosis.

Claims

1. A system for performing a therapeutic procedure in a target tissue region of a patient using focused ultrasound within a primary focal zone, comprising:

   an array of transducer elements (12);
   drive circuitry (14) coupled to the transducer elements (12), the drive circuitry (14) configured to provide respective drive signals (15) to the transducer elements (12) at , at least, first and second discrete frequencies; and
   a controller (16) coupled to the drive circuitry (14),

   characterized in that the controller (16) is configured for periodically changing the frequency of the respective drive signals (15) provided by the drive circuitry (14) between at least the first and second frequencies as often as every 0.2-0.5 seconds while substantially maintaining focus at the primary focal zone during a single sonication.

2. The system of claim 1, **characterized in that** the controller (16) is further configured for changing the respective drive signals (15) between a plurality of discrete frequencies in a predetermined sequence during a single, substantially continuous sonication.

3. The system of claim 1, **characterized in that** the controller (16) is further configured for controlling a phase component of the respective drive signals (15) provided to the transducer elements (12) to provide a predetermined size and shape of a focal zone (38) created by the transducer elements (12).

4. The system of claim 1, **characterized in that** the controller (16) is further configured for controlling a phase component of the respective drive signals (15) to focus the transducer elements (12) substantially at a primary focal zone at the first and second frequencies.

5. The system of claim 1, **characterized in that** the array of transducer elements (12) comprises a substantially concave concentric ring array of transducer elements (12).

6. The system of claim 1, **characterized in that** the array of transducer elements (12) comprises a sub-

stantially linear array of transducer elements (12).

7. The system of claim 1, **characterized in** further comprising a fluid-filled casing having the transducer elements (12) therein, the casing having a surface towards which the transducer elements (12) are oriented for acoustically coupling the transducer elements (12) to a patient in contact with the surface.

8. The system of claim 1, **characterized in** further comprising a positioner (34) connected to the transducer elements (12) for mechanically moving a focal zone (38) thereof.

9. A system for performing a therapeutic procedure in a target tissue region of a patient using focused ultrasound within a primary focal zone, comprising:

an array of transducer elements (12);
drive circuitry (14) coupled to the transducer elements (12), the drive circuitry (14) configured to provide respective drive signals (15) to the transducer elements (12) at, at least, first, second and third discrete frequencies; and
a controller (16) coupled to the drive circuitry (14),

characterized in that the controller (16) is configured for periodically changing the frequency of the respective drive signals (15) provided by the drive circuitry (14) between at least the first, second, and third frequencies as often as every 0.2-0.5 seconds while substantially maintaining focus at the primary focal zone during a single, substantially continuous sonication.

10. The system of claim 9, **characterized in that** the controller (16) is further configured for controlling a phase component of the respective drive signals (15) to focus the transducer elements (12) substantially at a primary focal zone at the first and second frequencies.

Patentansprüche

1. System zum Ausführen einer therapeutischen Prozedur in einem Zielgewebsbereich eines Patienten unter Verwendung von gebündeltem Ultraschall in einem primären Brennbereich, umfassend:

eine Anordnung von Transducerelementen (12);
Treiberschaltungen (14), die mit den Transducerelementen (12) verbunden sind, wobei die Treiberschaltungen (14) zum Bereitstellen der jeweiligen Treibersignale (15) für die Transducerelemente (12) bei mindestens ersten und zweiten diskreten Frequenzen ausgelegt sind; und
einen Controller (16), der mit den Treiberschaltungen (14) verbunden ist,

dadurch gekennzeichnet, daß der Controller (16) zum periodischen Ändern der Frequenz der jeweiligen Treibersignale (15), die von den Treiberschaltungen (14) bereitgestellt werden, mindestens zwischen der ersten und zweiten Frequenz jeweils nach 0,2-0,5 Sekunden ausgelegt ist, während gleichzeitig die Fokussierung auf den primären Brennbereich während einer einzelnen Beschallung aufrechterhalten ist.

2. System nach Anspruch 1, **dadurch gekennzeichnet, daß** der Controller (16) ferner zum Wechseln der jeweiligen Treibersignale (15) zwischen mehreren diskreten Frequenzen in einer vorgegebenen Folge während einer einzelnen, im wesentlichen kontinuierlichen Beschallung ausgelegt ist.

3. System nach Anspruch 1, **dadurch gekennzeichnet, daß** der Controller (16) ferner zum Kontrollieren einer Phasenkomponente der jeweiligen Treibersignale (15) ausgelegt ist, die für die Transducerelemente (12) bereitgestellt sind, um für eine vorgegebene Größe und Form eines Brennbereichs (38) zu sorgen, der durch die Transducerelemente (12) erzeugt ist.

4. System nach Anspruch 1, **dadurch gekennzeichnet, daß** der Controller (16) ferner zum Kontrollieren einer Phasenkomponente der jeweiligen Treibersignale (15) ausgelegt ist, um die Transducerelemente (12) im wesentlichen auf einen primären Brennbereich bei der ersten und zweiten Frequenz zu fokussieren.

5. System nach Anspruch 1, **dadurch gekennzeichnet, daß** die Anordnung von Transducerelementen (12) eine im wesentlichen konkave konzentrische Ringanordnung von Transducerelementen (12) umfaßt.

6. System nach Anspruch 1, **dadurch gekennzeichnet, daß** die Anordnung von Transducerelementen (12) eine im wesentlichen lineare Anordnung von Transducerelementen (12) umfaßt.

7. System nach Anspruch 1, **dadurch gekennzeichnet, daß** es ferner einen flüssigkeitsgefüllten Behälter umfaßt, der die Transducerelemente (12) darin enthält, wobei der Behälter eine Fläche hat, zu der die Transducerelemente (12) für die akustische Kopplung der Transducerelemente (12) mit einem Patienten in Kontakt mit der Fläche ausgerichtet sind.

8. System nach Anspruch 1, **dadurch gekennzeichnet, daß** es ferner einen Stellungsregler (34) umfaßt, der mit den Transducerelementen (12) zur mechanischen Verschiebung eines Brennbereichs (38) derselben verbunden ist.

9. System zum Ausführen einer therapeutischen Prozedur in einem Zielgewebsbereich eines Patienten unter Verwendung von gebündeltem Ultraschall in einem primären Brennbereich, umfassend:

   eine Anordnung von Transducerelementen (12);
   Treiberschaltungen (14), die mit den Transducerelementen (12) verbunden sind, wobei die Treiberschaltungen (14) zum Bereitstellen der jeweiligen Treibersignale (15) für die Transducerelemente (12) bei mindestens ersten, zweiten und dritten diskreten Frequenzen ausgelegt sind; und
   einen Controller (16), der mit den Treiberschaltungen (14) verbunden ist,
   dadurch gekennzeichnet, daß der Controller (16) zum periodischen Ändern der Frequenz der jeweiligen Treibersignale (15), die von den Treiberschaltungen (14) bereitgestellt sind, mindestens zwischen der ersten, zweiten und dritten Frequenz jeweils nach 0,2-0,5 Sekunden ausgelegt ist, während gleichzeitig die Fokussierung auf den primären Brennbereich während einer einzelnen, im wesentlichen kontinuierlichen Beschallung aufrechterhalten ist.

10. System nach Anspruch 9, **dadurch gekennzeichnet, daß** der Controller (16) ferner zum Kontrollieren einer Phasenkomponente der jeweiligen Treibersignale (15) ausgelegt ist, um die Transducerelemente (12) im wesentlichen auf einen primären Brennbereich bei der ersten und zweiten Frequenz zu fokussieren.

Revendications

1. Système pour effectuer une procédure thérapeutique dans une région de tissu cible d'un patient en utilisant des ultrasons concentrés à l'intérieur d'une zone focale principale, comprenant :

   un réseau d'éléments transducteurs (12) ;
   un circuit de pilotage (14) couplé aux éléments transducteurs (12), le circuit de pilotage (14) étant configuré pour fournir des signaux de pilotage respectifs (15) aux éléments transducteurs (12) à au moins une première fréquence discrète et une deuxième fréquence discrète ; et
   un contrôleur (16) couplé au circuit de pilotage (14),
   caractérisé en ce que le contrôleur (16) est configuré pour changer périodiquement la fréquence des signaux de pilotage respectifs (15) fournis par le circuit de pilotage (14) entre au moins la première fréquence et la deuxième fréquence toutes les 0,2 à 0,5 secondes tout en maintenant sensiblement la concentration sur la zone focale principale au cours d'une sonication unique.

2. Système selon la revendication 1, **caractérisé en ce que** le contrôleur (16) est en outre configuré pour changer les signaux de pilotage respectifs (15) entre une pluralité de fréquences discrètes dans une séquence prédéterminée au cours d'une seule sonication sensiblement continue.

3. Système selon la revendication 1, **caractérisé en ce que** le contrôleur (16) est en outre configuré pour commander un composant de phase des signaux de pilotage respectifs (15) fournis aux éléments transducteurs (12) pour fournir une taille prédéterminée et une forme prédéterminée d'une zone focale (38) créée par les éléments transducteurs (12).

4. Système selon la revendication 1, **caractérisé en ce que** le contrôleur (16) est en outre configuré pour commander un composant de phase des signaux de pilotage respectifs (15) pour concentrer les éléments transducteurs (12) sensiblement sur une zone focale principale à la première fréquence et à la deuxième fréquence.

5. Système selon la revendication 1, **caractérisé en ce que** le réseau d'éléments transducteurs (12) comprend un réseau d'anneaux concentriques sensiblement concave d'éléments transducteurs (12).

6. Système selon la revendication 1, **caractérisé en ce que** le réseau d'éléments transducteurs (12) comprend un réseau sensiblement linéaire d'éléments transducteurs (12).

7. Système selon la revendication 1, **caractérisé en outre en ce qu**'il comprend une structure remplie de fluide ayant les éléments transducteurs (12) à l'intérieur de celle-ci, la structure ayant une surface vers laquelle les éléments transducteurs (12) sont orientés pour coupler acoustiquement les éléments transducteurs (12) à un patient en contact avec la surface.

8. Système selon la revendication 1, **caractérisé en outre en ce qu**'il comprend un positionneur (34) connecté aux éléments transducteurs (12) pour déplacer mécaniquement une zone focale (38) de celui-ci.

9. Système pour effectuer une procédure thérapeutique dans une région de tissu cible d'un patient en utilisant des ultrasons concentrés à l'intérieur d'une zone focale principale, comprenant :

un réseau d'éléments transducteurs (12);
un circuit de pilotage (14) couplé aux éléments transducteurs (12), le circuit de pilotage (14) étant configuré pour fournir des signaux de pilotage respectifs (15) aux éléments transducteurs (12) à au moins une première fréquence discrète, une deuxième fréquence discrète et une troisième fréquence discrète ; et
un contrôleur (16) couplé au circuit de pilotage (14),
caractérisé en ce que le contrôleur (16) est configuré pour changer périodiquement la fréquence des signaux de pilotage respectifs (15) fournis par le circuit de pilotage (14) entre au moins la première fréquence, la deuxième fréquence et la troisième fréquence toutes les 0,2 à 0,5 secondes tout en maintenant sensiblement la concentration sur la zone focale principale au cours d'une sonication unique sensiblement continue.

10. Système selon la revendication 9, **caractérisé en ce que** le contrôleur (16) est en outre configuré pour commander un composant de phase des signaux de pilotage respectifs (15) pour concentrer les éléments transducteurs (12) sensiblement sur une zone focale principale à la première fréquence et à la deuxième fréquence.

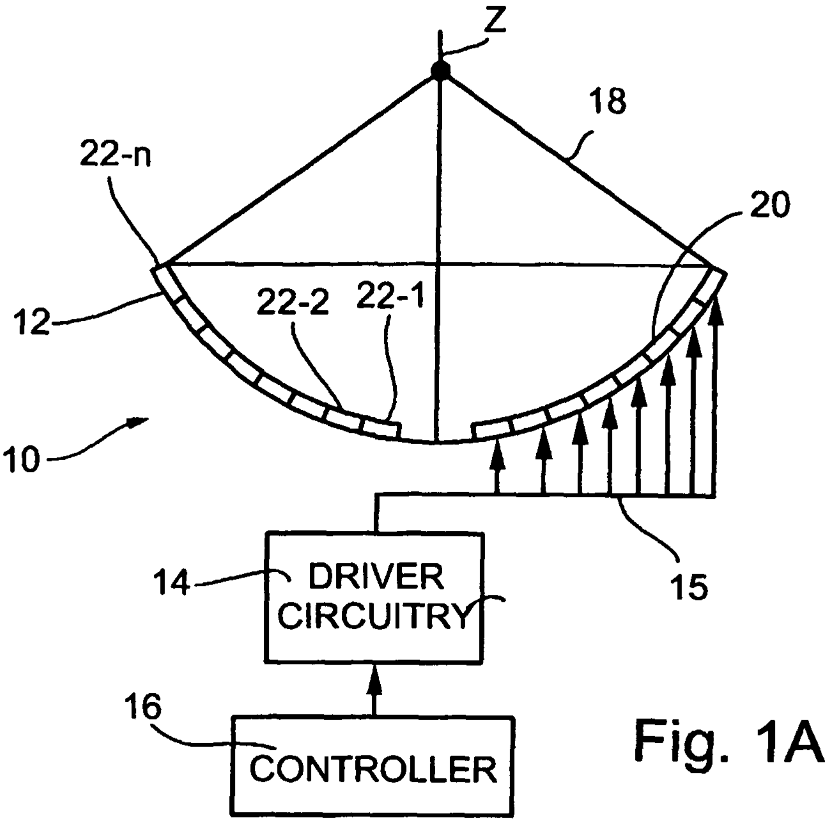
Z
18
22-n
20
12
22-2
22-1
10
14
DRIVER CIRCUITRY
15
16
CONTROLLER

Fig. 1A

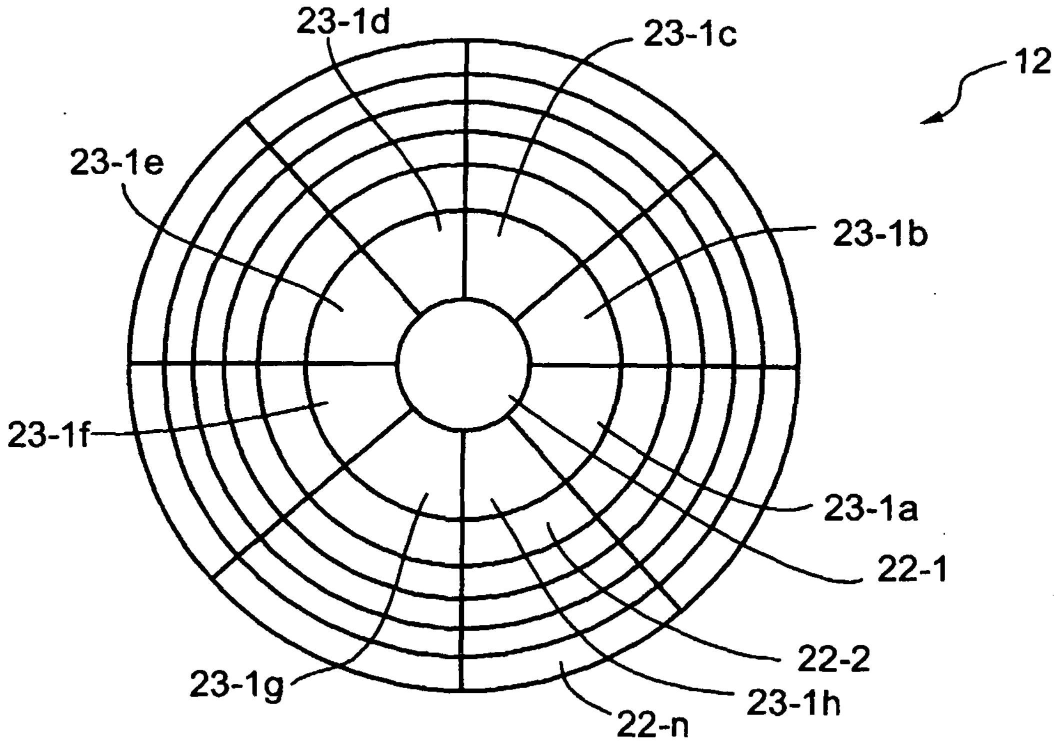
23-1d
23-1c
12
23-1e
23-1b
23-1f
23-1a
22-1
22-2
23-1g
23-1h
22-n

Fig. 1B

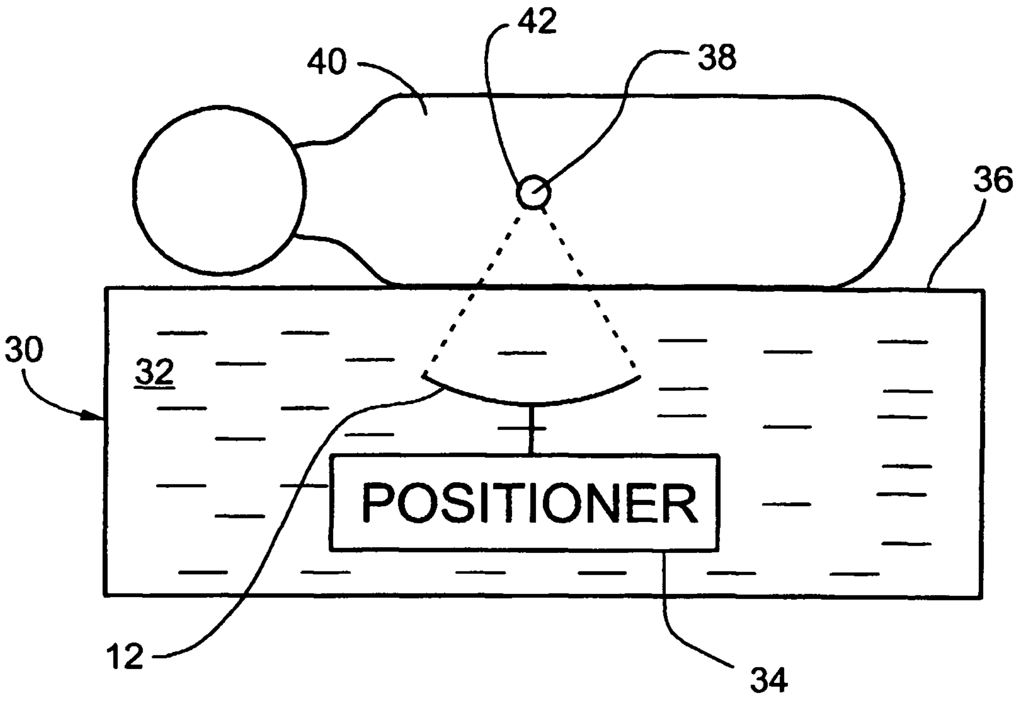
42
38
40
36
30
32
POSITIONER
12
34

Fig. 2

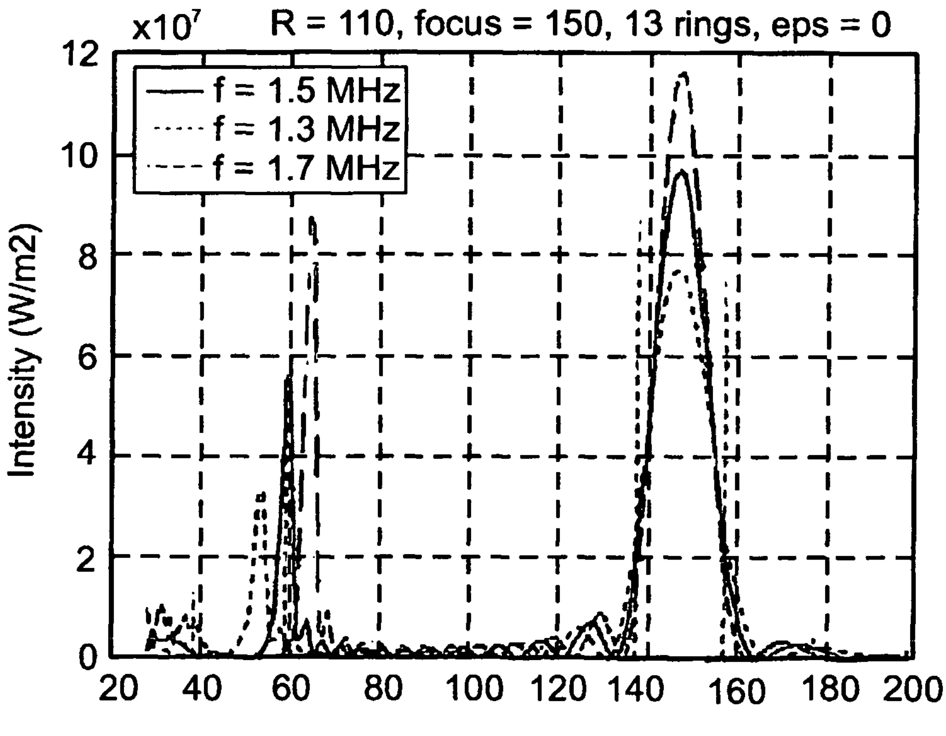
x10^7
R = 110, focus = 150, 13 rings, eps = 0
f = 1.5 MHz
f = 1.3 MHz
f = 1.7 MHz
Intensity (W/m2)
12
10
8
6
4
2
0
20
40
60
80
100
120
140
160
180
200

Fig. 3

REFERENCES CITED IN THE DESCRIPTION

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- **C. CAIN ; S. UMEMURA.** Concentric-Ring and Sector-Vortex Phased-Array Applicators for Ultrasound Hyperthermia. *Transactions on Microwave Theory and Techniques,* May 1986, vol. 34 (5), 542-551 **[0019]**

专利名称(译)	用于减少相控阵聚焦超声系统中的二次热点的系统		
公开(公告)号	[EP1274348B1](EP1274348B1)	公开(公告)日	2007-09-26
申请号	EP2001923937	申请日	2001-04-12
[标]申请(专利权)人(译)	TXSONICS		
申请(专利权)人(译)	TXSONICS LTD.		
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IPC分类号	A61B8/00 A61N7/02 B06B1/02 A61B18/00 A61B17/225 A61N7/00 G10K11/34 H01Q21/20 H04R3/00 H04R17/00		
CPC分类号	A61N7/02 A61B8/4494 A61N2007/0065 A61N2007/0073 A61N2007/0078 A61N2007/0095 B06B1/0284 G10K11/346		
优先权	09/556095 2000-04-21 US		
其他公开文献	EP1274348B8 EP1274348A4 EP1274348A2		
外部链接	Espacenet		

摘要(译)

用于使用聚焦超声执行治疗程序的系统和方法包括提供压电换能器，其包括多个换能器元件，例如凹入的同心环阵列或换能器元件的衬里阵列。 驱动电路耦合到换能器，用于以多个离散RF频率之一向换能器元件提供驱动信号。 控制器耦合到驱动电路，用于周期性地将驱动信号的频率改变为多个离散频率之一，同时控制驱动信号的相位分量以在单个过程中将换能器的聚焦保持在主聚焦区。 声波处理。