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(54) ULTRASONIC ENERGY DISPLAY DEVICE

ULTRASCHALLENERGIEANZEIGEVORRICHTUNG

DISPOSITIF D’AFFICHAGE D’ÉNERGIE ULTRASONORE

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(73) Proprietor: **Chang Gung University**
Taoyuan County 333 (TW)

(72) Inventors:
- **LIU, Hao-Li**
  Taoyuan City 33302 (TW)
- **XIA, Jing-Jing**
  Taoyuan City 33302 (TW)

(74) Representative: **Lang, Christian**
LangPatent Anwaltskanzlei
Ingolstädter Straße 5
80807 München (DE)

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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a display device, particularly to a display device for ultrasound energy.

Description of the Related Art

[0002] The conventional focusing-type ultrasonic apparatus can generate focused function by selecting suitable frequency range of 200k Hz to 2 MHz. Meantime, the focused area has sufficient high acoustic pressure so that capable of inducing localized blood-brain barrier (BBB) disruption, which is an important implication on noninvasively delivering drug into brain. Although the conventional focusing-type ultrasonic apparatus can induce localized blood-brain barrier (BBB) disruption temporarily, yet they are still high-frequency ultrasonic systems. Thus the invasive way has to be used to induce BBB disruption, and it still is concentrated to a small area. It is unable to reach the work of inducing larger area of BBB disruption. Also, the cost of system is pretty high and there are no more extensive applications.

[0003] Although the high-frequency ultrasonic system is easier to focus energy to the focal point, most energy is easy to be absorbed by hard tissues such as skull etc., thus the ultrasonic effect will be reduced. It can only be operated after the animal skull being removed; thus the high-frequency ultrasonic system is still an invasive drug release brain therapy system. Due to ultrasonic energy can only focus to a single focal point, it is unable to induce larger area of BBB disruption effectively. If one wants the apparatus to open BBB without removing the skull, then the ultrasound energy cannot be too low. However, too much ultrasound energy can directly damage capillary rather than opening the tight junctions. There are some technologies such as acoustic radiation force imaging that applies a sufficiently high and continuous-wave mode ultrasound to detect acoustic patterns; however, the receiving time of the technology is too long so that the distribution of signals is hard to be identified. Besides, since the excessive ultrasound energy required by this technology typically induces thermally and mechanically damages organism tissue, the purpose of using such technology to monitor the blood-to-brain permeability is not practical. To overcome the abovementioned problems, the present invention provides a display device for ultrasound energy, so as to solve the aforementioned problems of the prior art.

[0004] Patent specification US 6508774 B1 discloses an ultrasonic therapy apparatus having the features of the preamble of claims 1 and 5, wherein a plurality of transducers can be used as a sparse imaging array to derive an image of the interface and tissues adjacent the transducer array of the apparatus. A further processing system for confocally emitting and receiving ultrasound is known from patent application publication US 2015/0182195 A1.

SUMMARY OF THE INVENTION

[0005] A primary objective of the present invention is to provide a display device for ultrasound energy, which controls a focused ultrasound emitting and receiving device to emit an ultrasound signal to an organism and, after an estimation period, receive the backscattering ultrasound signal, thereby generating an image of the organism. Wherein, brightness of the image is directly proportional to energy intensity of the ultrasound signal. This invention can be applied for monitoring the induction of BBB opening and drug delivery.

[0006] To achieve the abovementioned objectives, the present invention provides a display device for ultrasound energy, which comprises the features of claims 1 or 5. Further embodiments are subject-matter of the dependent claims. The display device for ultrasound energy according to the invention comprises a focused ultrasound emitting and receiving device, a processing device and a display. The focused ultrasound emitting and receiving device emits at least one first ultrasound signal to a target position of an organism, and the target position reflects the first ultrasound signal to form at least one second ultrasound signal. The processing device is connected with the focused ultrasound emitting and receiving device and sets an estimation period according to a distance between the focused ultrasound emitting and receiving device and the target position as well as a given sound traveling speed. The processing device generates a first electrical signal and transmits the first electrical signal to the focused ultrasound emitting and receiving device to control the focused ultrasound emitting and receiving device to emit the first ultrasound signal, and then the processing device drives the focused ultrasound emitting and receiving device to start to receive the second ultrasound signal only during a preset period after the estimation period. The preset period is equal to or larger than response time of the focused ultrasound emitting and receiving device. The display is connected with the processing device. The processing device display a first image of the target position according to the second ultrasound signal, and brightness of the first image is directly proportional to energy intensity of the first ultrasound signal.

[0007] Below, the embodiments are described in detail in cooperation with the drawings to make easily understood the technical contents, characteristics and accomplishments of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008]

Fig.1 is a block diagram showing a device according to an embodiment of the present invention;
Fig.2 is a diagram schematically showing focused ultrasound transducers arranged into a two-dimensional array according to an embodiment of the present invention;
Fig.3 is a diagram schematically showing focused ultrasound transducers arranged into a concentric circle array according to an embodiment of the present invention;
Fig.4 is a flowchart diagram showing operation of the device according to an embodiment of the present invention;
Fig.5 is a diagram schematically showing a focused ultrasound emitting and receiving device formed by a plurality of ultrasound emitters and an ultrasound receiver according to an embodiment of the present invention;
Fig.6 is a diagram schematically showing a focused ultrasound emitting and receiving device formed by an ultrasound emitter and a plurality of ultrasound receivers according to an embodiment of the present invention;
Fig.7(a) is a diagram showing an image of blood-brain barrier (BBB) opened effect observed from stained brain tissues under sound pressure of 0.467 MPa according to an embodiment of the present invention;
Fig.7(b) is a diagram showing a second image corresponding to Fig.7(a);
Fig.8(a) is a diagram showing an image of blood-brain barrier (BBB) opened effect observed from stained brain tissues under sound pressure of 0.705 MPa according to an embodiment of the present invention;
Fig.8(b) is a diagram showing a second image corresponding to Fig.8(a); and
Fig.9 is a diagram showing proportional relationship between energy intensity of an ultrasound signal and sound pressure according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0009] Below is the first embodiment of the present invention. Refer to Fig.1, Fig.2 and Fig.3. The present invention comprises a focused ultrasound emitting and receiving device 10, a processing device 14 and a display 16. The processing device 14 is connected with the focused ultrasound emitting and receiving device 10 and the display 16. The position of the focused ultrasound emitting and receiving device 10 corresponds to a target position of an organism 17. For example, the organism 17 is a central nervous system (CNS) tissue with the microvascular structure containing blood-brain barrier (BBB) for each CNS capillary. The focused ultrasound emitting and receiving device 10 further comprises at least one focused ultrasound transducer 18 or a plurality of focused ultrasound transducers 18. In the first embodiment, the focused ultrasound emitting and receiving device 10 comprises a plurality of focused ultrasound transducers 18 arranged into a two-dimensional square-diced array or a concentric ring-shape array on a curved surface, wherein the two-dimensional square-diced array or a concentric ring-shape array are respectively shown in Fig.2 and Fig.3.

[0010] According to a distance between the ultrasound transducer 18 and the target position and sound-traveling speed, the processing device 14 sets an estimation period. For example, there is a distance between the target position and the focused ultrasound transducer 18 farthest from the target position, and the estimation period equals the distance multiplied by 2 and divided by the sound-traveling speed. The processing device 14 generates a first electrical signal E1 and transmits the first electrical signal E1 to the focused ultrasound transducers 18 to control the focused ultrasound transducers 18 to emit at least one first ultrasound signal U1 to the target position. The first ultrasound signal U1 penetrates through cranial bone to reach the target position. The target position reflects the first ultrasound signal U1 to form at least one second ultrasound signal U2. In the first embodiment, there are a plurality of first ultrasound signals U1 and a plurality of second ultrasound signals U2. After generating the first electrical signal E1, the processing device 14 drives the focused ultrasound transducers 18 to start to receive the second ultrasound signals U2 penetrating through the cranial bone only during a preset period after the estimation period. The processing device 14 drives the focused ultrasound transducers 18 to stop receiving any ultrasound signals during the other period. The preset period is equal to or larger than response time of the focused ultrasound transducer 18. The processing device 14 uses the display 16 to display a first image of the target position according to the second ultrasound signals U2. Since energy intensity of the first ultrasound signals U1 is directly proportional to energy intensity of the second ultrasound signals U2 and brightness of the first image is directly proportional to the energy intensity of the second ultrasound signals U2, the brightness of the first image is directly proportional to the energy intensity of the first ultrasound signals U1. The processing device 14 converts the first electrical signal E1 into a second electrical signal E2 received by the focused ultrasound transducers 18 according to a difference between the brightness of the first image and preset brightness. The focused ultrasound transducers 18 use the second electrical signal E2 to emit at least one third ultrasound signal U3 whose energy intensity larger than energy intensity of the first ultrasound signal U1 to the target position. The third ultrasound signal U3 penetrates through the cranial bone to reach the target position. The target position reflects the third ultrasound signal U3 to form at least one fourth ultrasound signal U4. In the first embodiment, there are a plurality of third ultrasound signals U3 and a plurality of fourth ultrasound signals U4. After generating the third ultrasound signals U3, the processing device 14 drives the focused ultrasound transducers 18 to start to receive the fourth ultrasound signals U4 through the cranial bone only during the preset period after the estimation period. The processing device 14 drives the focused ultrasound transducers 18 to stop receiving any ultrasound signals during the other period. The first ultrasound signals U1, the second ultrasound signals U2, the third ultrasound signals U3 and the fourth ultrasound signals U4 are burst-tone waves. The higher the frequency of the first ultrasound signals U1, the second ultrasound signals U2, the third ultrasound signals U3 and the fourth ultrasound signals U4 is, the thinner the thickness of the cranial bone penetrated are. In other words, the frequency of the first ultrasound signal U1, the second ultrasound signal U2, the third ultrasound signal U3 and the fourth ultrasound signal U4 is inversely proportional to the thickness of the cranial bone penetrated. The processing device 14 uses the display 16 to display a second image of the target position according to the fourth ultrasound signals U4. Since energy intensity of the third ultrasound signals U3 is directly proportional to energy intensity of the fourth ultrasound signals U4 and brightness of the second image is directly proportional to the energy intensity of the fourth ultrasound signals U4, the brightness of the second image is directly proportional to the energy intensity of the third ultrasound signals U3.

[0011] Below is the operation process of the first embodiment, as shown in Fig.4. Firstly, a calibration process is performed. The calibration process comprises Step S10, Step S12 and Step S14. In the beginning, Step S10 is performed. In Step S10, the processing device 14 generates the first electrical signal E1 and transmits the first electrical signal E1 to the focused ultrasound transducers 18 to control the focused ultrasound transducers 18 to emit the first ultrasound signals U1 to the target position. Then, in Step S12, the first ultrasound signals U1 penetrate through the cranial bone to reach the target position and the target position reflects the first ultrasound signals U1 to form the second ultrasound signals U2 in the estimation period. The processing device 14 drives the focused ultrasound transducers 18 to start to receive the second ultrasound signals U2 through the cranial bone only during the preset period after the estimation period. Then, in Step S14, the processing device 14 uses the display 16 to display the first image of the target position according to the second ultrasound signals U2, whereby the brightness of the first image is directly proportional to the energy intensity of the first ultrasound signals U1.

[0012] The first image is displayed according to first beamformed filtered data $\tilde{rf}(x_g, z_g)$, and the first beamformed filtered data $\tilde{rf}(x_g, z_g)$ satisfies following formulas (1), (2), (3), (4) and (5):

$$\tilde{rf}(x_g, z_g) = F \times \sum_{n=1}^{N}\left(\sum_{n=1}^{N}\left((\hat{RF}_{M\times N})^T \times x_{M\times 1} \times \overline{TD_{1\times N}}\right)\right) \tag{1}$$

$$\begin{aligned}\hat{RF}_{M\times N} \cong{}& \cos(2\pi f_r t)\times(\hat{chRF}_{M\times N} + \hat{chRF}_{M\times N}^{*})/2 \\ & -\sin(2\pi f_r t)\times(-j)\times(\hat{chRF}_{M\times N} + \hat{chRF}_{M\times N}^{*})/2\end{aligned} \tag{2}$$

$$\hat{IQ}_{m\times N} \cong [f_1(k), f_2(k), \ldots, f_i(k), \ldots, f_N(k)] \tag{3}$$

$$\begin{aligned}\hat{chRF}_{M\times N} \cong{}& [f_1(\frac{k}{f_{sIQ}} * f_{sRF}), f_2(\frac{k}{f_{sIQ}} * f_{sRF}), \ldots \\ & , f_i(\frac{k}{f_{sIQ}} * f_{sRF}), \ldots, f_N(\frac{k}{f_{sIQ}} * f_{sRF})]\end{aligned} \tag{4}$$

$$T_{M\times N} = x_{M\times 1} \times \overline{TD_{1\times N}} \tag{5}$$

[0013] Wherein, (x_g,z_g) is 3-D coordinate of the target position, and F is a first filtered factor, and N is an amount of the focused ultrasound transducer 18, and n is an index of each focused ultrasound transducer 18, and $\hat{RF}_{M\times N}$ is a first beamformed data matrix with dimension $M\times N$, and t is time, and f_r is a first re-modulation frequency, and $\hat{chRF}_{M\times N}$ is a first channel data matrix with dimension $M\times N$, and $\hat{IQ}_{m\times N}$ is a matrix with dimension $m\times N$ of a baseband signal of the second ultrasound signal U2, and m is a natural number, and $f_i(k)$ is a column function of a i-th column of $\hat{IQ}_{m\times N}$, and k and i are natural numbers, and k = 1,2,...,m, and i = 1,2,...,N, and f_{sIQ} is a sampling frequency of $\hat{IQ}_{m\times N}$, and f_{sRF} is a resampled frequency of $\hat{IQ}_{m\times N}$, and $\overline{TD_{1\times N}}$ is a first time backscattered data matrix of the second ultrasound signal U2 moving from the target position to N pieces of the focused ultrasound transducers, and $T_{M\times N}$ is a matrix with dimension $M\times N$ comprising elements 0 and 1, and M is a natural number larger than the largest element of the first time matrix, and $x_{M\times 1}$ is a vector with dimension $M\times 1$, and $\hat{chRF}_{M\times N}^{*}$ is a conjugation of $\hat{chRF}_{M\times N}$.

[0014] The energy intensity of the first ultrasound signals U1 is relatively low in ultrasound energy level. An excessive energy intensity of the first ultrasound signals U1 can damage the organism 17. As a result, the low energy intensity of the first ultrasound signals U1 applies to the organism 17, so as to know how much energy applied to the organism 17 and how much energy absorbed by the cranial bone. The processing device 14 knows how much energy applied to the organism 17 according to the brightness of the first image. The higher the brightness of the first image is, the stronger the energy applied to the target position of the organism 17 is. The processing device 14 of the present invention sets the preset brightness as an energy level intended to apply to the target position of the organism 17.

[0015] After the calibration process, an execution process is performed. The execution process comprises Step S16, Step S18 and Step S20. In the execution process, Step S16 is firstly performed. In Step S16, the processing device 14 converts the first electrical signal E1 into the second electrical signal E2 received by the focused ultrasound transducers 18 according to the difference between the brightness of the first image and the preset brightness, whereby the focused ultrasound transducers 18 use the second electrical signal E2 to emit the third ultrasound signals U3 whose energy intensity larger than the energy intensity of the first ultrasound signals U1 to the target position. Then, in Step S18, the third ultrasound signals U3 penetrate through the cranial bone to reach the target position and the target position reflects the third ultrasound signals U3 to form the fourth ultrasound signals U4 in the estimation period. The processing device 14 drives the focused ultrasound transducers 18 to start to receive the fourth ultrasound signals U4 through the cranial bone only during the preset period after the estimation period. Then, in Step S20, the processing device 14 uses the display 16 to display the second image of the target position according to the fourth ultrasound signals U4, whereby the brightness of the second image is directly proportional to the energy intensity of the third ultrasound signals U3.

[0016] The second image is displayed according to second beamformed filtered data $\tilde{rf}(x_g,z_g)'$, and the second beamformed filtered data $\tilde{rf}(x_g,z_g)'$ satisfies following formulas (6), (7), (8), (9) and (10):

$$\tilde{rf}(x_g,z_g)' = F'\times\sum_{n=1}^{N}\left(\sum_{n=1}^{N}\left(\left(\hat{RF}'_{M'\times N}\right)^{T}\times x'_{M'\times 1}\times\overline{TD'_{1\times N}}\right)\right) \qquad (6)$$

$$\begin{aligned}\hat{RF}'_{M'\times N} \cong{}& \cos(2\pi f_r' t)\times\left(\hat{chRF}'_{M'\times N}+\hat{chRF}'^{*}_{M'\times N}\right)/2\\ &-\sin(2\pi f_r' t)\times(-j)\times\left(\hat{chRF}'_{M'\times N}+\hat{chRF}'^{*}_{M'\times N}\right)/2\end{aligned} \qquad (7)$$

$$\hat{IQ}'_{m\times N} \cong [f_1'(k), f_2'(k), \dots, f_i'(k), \dots, f_N'(k)] \tag{8}$$

$$\begin{aligned}\hat{chRF}'_{M'\times N} \cong {} & [f_1'(\frac{k}{f_{sIQ}'} * f_{sRF}'), f_2'(\frac{k}{f_{sIQ}'} * f_{sRF}'), \dots \\ & , f_i'(\frac{k}{f_{sIQ}'} * f_{sRF}'), \dots, f_N'(\frac{k}{f_{sIQ}'} * f_{sRF}')]\end{aligned} \tag{9}$$

$$T'_{M'\times N} = x'_{M'\times 1} \times \overline{TD'}_{1\times N} \tag{10}$$

[0017] Wherein, (x_g,z_g) is 3-D coordinate of the target position, and F' is a second filtered factor, and N is an amount of the focused ultrasound transducer 18, and n is an index of each focused ultrasound transducer 18, and $\hat{RF}'_{M'\times N}$ is a second beamformed data matrix with dimension $M'\times N$, and t is time, and f_r' is a second re-modulation frequency, and $\hat{chRF}'_{M'\times N}$ is a second channel data matrix with dimension $M'\times N$, and $\hat{IQ}'_{m\times N}$ is a matrix with dimension $m\times N$ of a baseband signal of the fourth ultrasound signal U4, and m is a natural number, and $f_i'(k)$ is a column function of a i-th column of $\hat{IQ}'_{m\times N}$, and k and i are natural numbers, and k = 1,2,...,m, and i = 1,2,...,N, and f_{sIQ}' is a sampling frequency of $\hat{IQ}'_{m\times N}$, and f_{sRF}' is a resampled frequency of $\hat{IQ}'_{m\times N}$, and $\overline{TD'_{1\times N}}$ is a second time matrix of the fourth ultrasound signal U4 moving from the target position to N pieces of the focused ultrasound transducers 18, and $T_{M\times N}$ is a matrix with dimension $M'\times N$ comprising elements 0 and 1, and M' is a natural number larger than the largest element of the second time matrix, and $x'_{M\times 1}$ is a vector with dimension $M'\times 1$, and $\hat{chRF}'^{*}_{M'\times N}$ is a conjugation of $\hat{chRF}'_{M'\times N}$.

[0018] After Step S20, the operation process returns to Step S10 to sequentially perform the calibration process and the execution process on another target position. Repeatedly, an activity of applying energy to a therapy region in CNS tissue is completed to achieve the purpose of opening the BBB and delivering drugs.

[0019] Below is the second embodiment of the present invention. Refer to Fig.1, Fig.5 and Fig.6. The second embodiment is different from the first embodiment in internal elements of the focused ultrasound emitting and receiving device 10. In the second embodiment, the focused ultrasound emitting and receiving device 10 further comprises at least one focused ultrasound emitter 20 and at least one focused ultrasound receiver 22 connected with the processing device 14. The focused ultrasound emitter 20 is surrounded by the focused ultrasound receiver 22. The preset period is equal to or larger than response time of the focused ultrasound receiver 22. There is a distance between the target position and the focused ultrasound receiver 22 farthest from the target position. The estimation period equals the distance multiplied by 2 and divided by sound-traveling speed. In the second embodiment, there is a plurality of focused ultrasound emitters 20 arranged into a strip array with one dimension, and an amount of the focused ultrasound receiver 22 is one. The focused ultrasound emitters 20 and the focused ultrasound receiver 22 are arranged on a curved surface, as shown in Fig.5. In this case, there are a plurality of first ultrasound signals U1, a plurality of second ultrasound signals U2, a plurality of third ultrasound signals U3 and a plurality of fourth ultrasound signals U4. Alternatively, an amount of the focused ultrasound emitter 20 is one, and there is a plurality of focused ultrasound receivers 22. The focused ultrasound emitter 20 and the focused ultrasound receivers 22 are arranged into a ring array on a curved surface, as shown in Fig.6. In this case, there are one first ultrasound signal U1, one second ultrasound signal U2, one third ultrasound signal U3 and one fourth ultrasound signal U4.

[0020] Below is the operation process of the second embodiment, as shown in Fig.4. Firstly, a calibration process is performed. The calibration process comprises Step S10, Step S12 and Step S14. In the beginning, Step S10 is performed. In Step S10, the processing device 14 generates the first electrical signal E1 and transmits the first electrical signal E1 to the focused ultrasound emitter 20 to control the focused ultrasound emitter 20 to emit the first ultrasound signal U1 to the target position. Then, in Step S12, the first ultrasound signal U1 penetrates through cranial bone to reach the target position and the target position reflects the first ultrasound signal U1 to form the second ultrasound signal U2 in the estimation period. The processing device 14 drives the focused ultrasound receiver 22 to start to receive the second ultrasound signal U2 through the cranial bone only during the preset period after the estimation period. Then, in Step S14, the processing device 14 uses the display 16 to display the first image of the target position according to the second ultrasound signal U2, whereby the brightness of the first image is directly proportional to the energy intensity of the first ultrasound signal U1.

[0021] The first image is displayed according to first beamformed filtered data $\tilde{rf}(x_g, z_g)$, and the first beamformed filtered data $\tilde{rf}(x_g, z_g)$ satisfies following formulas (11), (12), (13), (14) and (15):

$$\tilde{rf}(x_g, z_g) = F \times \sum\nolimits_{n=1}^{N} \left(\sum\nolimits_{n=1}^{N} \left((\hat{RF}_{M\times N})^T \times x_{M\times 1} \times \overline{TD_{1\times N}} \right) \right) \tag{11}$$

$$\begin{aligned} \hat{RF}_{M\times N} &\cong \cos(2\pi f_r t) \times (\hat{chRF}_{M\times N} + \hat{chRF}_{M\times N}^{*})/2 \\ &\quad - \sin(2\pi f_r t) \times (-j) \times (\hat{chRF}_{M\times N} + \hat{chRF}_{M\times N}^{*})/2 \end{aligned} \tag{12}$$

$$\hat{IQ}_{m\times N} \cong [f_1(k), f_2(k), \ldots, f_i(k), \ldots, f_N(k)] \tag{13}$$

$$\begin{aligned} \hat{chRF}_{M\times N} &\cong [f_1(\frac{k}{f_{sIQ}} * f_{sRF}), f_2(\frac{k}{f_{sIQ}} * f_{sRF}), \ldots \\ &\quad , f_i(\frac{k}{f_{sIQ}} * f_{sRF}), \ldots, f_N(\frac{k}{f_{sIQ}} * f_{sRF})] \end{aligned} \tag{14}$$

$$T_{M\times N} = x_{M\times 1} \times \overline{TD_{1\times N}} \tag{15}$$

[0022] Wherein, (x_g,z_g) is 3-D coordinate of the target position, and F is a first filtered factor, and N is an amount of the focused ultrasound receiver 22, and n is an index of each focused ultrasound receiver 22, and $\hat{RF}_{M\times N}$ is a first beamformed data matrix with dimension $M\times N$, and t is time, and f_r is a first re-modulation frequency, and $\hat{chRF}_{M\times N}$ is a first channel data matrix with dimension $M\times N$, and $\hat{IQ}_{m\times N}$ is a matrix with dimension $m\times N$ of a baseband signal of the second ultrasound signal U2, and m is a natural number, and $f_i(k)$ is a column function of a i-th column of $\hat{IQ}_{m\times N}$, and k and i are natural numbers, and k = 1,2, ..., m, and i = 1,2,...,N, and f_{sIQ} is a sampling frequency of $\hat{IQ}_{m\times N}$, and

f_{sRF} is a resampled frequency of $\hat{IQ}_{m\times N}$, and $\overline{TD_{1\times N}}$ is a first time matrix of the second ultrasound signal U2 moving from the target position to N pieces of the focused ultrasound receivers 22, and $T_{M\times N}$ is a matrix with dimension $M\times N$ comprising elements 0 and 1, and M is a natural number larger than the largest element of the first time matrix, and $x_{M\times 1}$ is a vector with dimension $M\times 1$, and $\hat{chRF}_{M\times N}^{*}$ is a conjugation of $\hat{chRF}_{M\times N}$.

[0023] Like the first embodiment, the second embodiment uses the processing device 14 to set the preset brightness as an energy level intended to apply to the target position of the organism 17.

[0024] After the calibration process, an execution process is performed. The execution process comprises Step S16, Step S18 and Step S20. In the execution process, Step S16 is firstly performed. In Step S16, the processing device 14 converts the first electrical signal E1 into the second electrical signal E2 received by the focused ultrasound emitter 20 according to the difference between the brightness of the first image and the preset brightness, whereby the focused ultrasound emitter 20 uses the second electrical signal E2 to emit the third ultrasound signal U3 whose energy intensity larger than the energy intensity of the first ultrasound signal U1 to the target position. Then, in Step S18, the third ultrasound signal U3 penetrates through the cranial bone to reach the target position and the target position reflects the third ultrasound signal U3 to form the fourth ultrasound signal U4 in the estimation period. The processing device 14 drives the focused ultrasound receiver 22 to start to receive the fourth ultrasound signal U4 through the cranial bone only during the preset period after the estimation period. Then, in Step S20, the processing device 14 uses the display 16 to display the second image of the target position according to the fourth ultrasound signal U4, whereby the brightness of the second image is directly proportional to the energy intensity of the third ultrasound signal U3.

[0025] The second image is displayed according to second beamformed filtered data $\tilde{rf}(x_g,z_g)'$, and the second beamformed filtered data $\tilde{rf}(x_g,z_g)'$ satisfies following formulas (16), (17), (18), (19) and (20):

$$\tilde{rf}(x_g,z_g)' = F'\times\sum_{n=1}^{N}\left(\sum_{n=1}^{N}\left(\left(\hat{RF}'_{M'\times N}\right)^{T}\times x'_{M'\times 1}\times\overline{TD'_{1\times N}}\right)\right) \tag{16}$$

$$\begin{aligned}\hat{RF}'_{M'\times N} \cong{}& \cos(2\pi f_r' t)\times\left(\hat{chRF}'_{M'\times N}+\hat{chRF}'^{*}_{M'\times N}\right)/2\\ &-\sin(2\pi f_r' t)\times(-j)\times\left(\hat{chRF}'_{M'\times N}+\hat{chRF}'^{*}_{M'\times N}\right)/2\end{aligned} \tag{17}$$

$$\hat{IQ}'_{m\times N} \cong [f_1'(k), f_2'(k),\ldots, f_i'(k),\ldots, f_N'(k)] \tag{18}$$

$$\begin{aligned}\hat{chRF}'_{M'\times N} \cong{}& [f_1'(\frac{k}{f_{sIQ}'}*f_{sRF}'), f_2'(\frac{k}{f_{sIQ}'}*f_{sRF}'),\ldots, f_i'(\frac{k}{f_{sIQ}'}*f_{sRF}'),\\ &\ldots, f_N'(\frac{k}{f_{sIQ}'}*f_{sRF}')]\end{aligned} \tag{19}$$

$$T'_{M'\times N} = x'_{M'\times 1}\times\overline{TD'_{1\times N}} \tag{20}$$

[0026] Wherein, (x_g,z_g) is coordinates of the target position, and F' is a second filtered factor, and N is an amount of the focused ultrasound receiver 22, and *n* is an index of each focused ultrasound receiver 22, and $\hat{RF}'_{M'\times N}$ is a second beamformed data matrix with dimension *M'*×*N*, and *t* is time, and f_r' is a second re-modulation frequency, and $\hat{chRF}'_{M'\times N}$ is a second channel data matrix with dimension *M'*×*N*, and $\hat{IQ}'_{m\times N}$ is a matrix with dimension *m*×*N* of a baseband signal of the fourth ultrasound signal U4, and m is a natural number, and $f_i'(k)$ is a column function of a i-th column of $\hat{IQ}'_{m\times N}$, and k and i are natural numbers, and k = 1,2,...,m, and i = 1,2,...,N, and f_{sIQ}' is a sampling frequency of $\hat{IQ}'_{m\times N}$, and f_{sRF}' is a resampled frequency of $\hat{IQ}'_{m\times N}$, and $\overline{TD'_{1\times N}}$ is a second time matrix of the fourth ultrasound signal U4 moving from the target position to *N* pieces of the focused ultrasound receivers 22, and $T'_{M\times N}$ is a matrix with dimension *M'*×*N* comprising elements 0 and 1, and *M'* is a natural number larger than the largest element of the second time matrix, and $x'_{M'\times 1}$ is a vector with dimension *M'*×1, and $\hat{chRF}'^{*}_{M'\times N}$ is a conjugation of $\hat{chRF}'_{M'\times N}$.

[0027] After Step S20, the operation process returns to Step S10 to sequentially perform the calibration process and the execution process on another target position. Repeatedly, an activity of applying energy to a therapy region of the BBB is also completed to achieve the purpose of opening the BBB in CNS tissue and delivering drugs.

[0028] The suitable ultrasound energy intensity can open the BBB at the targeted focused region without damaging the CNS capillary structure. In that circumstances, the stronger the energy intensity of ultrasound applied to the CNS target is, the more BBB opens and the higher the brightness of the second image is. Refer to Fig.7(a) and Fig.7(b) which are respectively a diagram of an image of CNS tissue under sound pressure of 0.467 MPa and a diagram of the second image corresponded thereof, wherein the input power of the third ultrasound signal is 4.54 W. From the figures, it is known that the ultrasound energy applies to the position of the CNS tissue having deeper color and the second image corresponding to the deeper color position has higher brightness. Refer to Fig.8(a) and Fig.8(b) which are respectively a diagram of an image of BBB under sound pressure of 0.705 MPa and a diagram of the second image corresponded thereof, wherein the energy of the third input electrical power is 9.12 W. From the figures, it is known that the ultrasound energy applies to the position of the BBB having deeper color and the second image corresponding to the deeper color position has higher brightness. Compared with Fig.7(b), Fig.8(b) has higher brightness. This is because the energy intensity of the third ultrasound signal increases. In addition, Fig.9 is a diagram showing proportional relationship between energy intensity of the emitted ultrasound signal and the sound pressure applied to BBB, wherein a pentagon denotes unopened BBB, a circle denotes opened BBB with low level, a quadrilateral denotes opened BBB with high level, and a triangle denotes an error bar of the three abovementioned data. From Fig.9, it is known that the energy intensity of the emitted ultrasound signal is directly proportional to the sound pressure applied to the targeted CNS tissue and cause various level of BBB opening, as shown by a dash line.

[0029] In conclusion, the present invention emits an ultrasound signal to an targeted CNS organism. Then, after an estimation period, the present invention starts to receive the backscattering ultrasound signal, thereby generating an image of the targeted CNS organism. Wherein, brightness of the image is directly proportional to energy intensity of the ultrasound signal to know how much energy applied to the organism and achieve the purpose of opening the BBB and delivering drugs.

[0030] The embodiments described above are only to exemplify the present invention but not to limit the scope of the present invention being defined by the appended claims.

Claims

1. A display device for ultrasound energy comprising:

a focused ultrasound emitting and receiving device (10) for emitting at least one first ultrasound signal (U1) to a target position of an organism (17), wherein said target position reflects said first ultrasound signal (U1) to form at least one second ultrasound signal (U2);

a processing device (14) connected with said focused ultrasound emitting and receiving device (10) for setting an estimation period according to a distance between said focused ultrasound emitting and receiving device (10) and said target position and sound-traveling speed, wherein said processing device (14) is configured to generate a first electrical signal (E1) and transmit said first electrical signal (E1) to said focused ultrasound emitting and receiving device (10) to control said focused ultrasound emitting and receiving device (10) to emit said first ultrasound signal (U1), wherein then said processing device (14) is configured to drive said focused ultrasound emitting and receiving device (10) to start to receive said second ultrasound signal (U2) only during a preset period after said estimation period, wherein said preset period is equal to or larger than response time of said focused ultrasound emitting and receiving device (10);

wherein said focused ultrasound emitting and receiving device (10) further comprises a plurality of focused ultrasound transducers (18) for receiving said first electrical signal (E1) to generate said first ultrasound signal (U1) according to said first electrical signal (E1), wherein said processing device (14) is configured to drive said focused ultrasound transducers (18) to receive said second ultrasound signal (U2), wherein said preset period is equal to or larger than response time of said focused ultrasound transducers (18),

wherein

a display (16) is connected with said processing device (14), **characterised in that** said processing device (14) is configured to use said display (16) to display a first image of said target position according to said second ultrasound signal (U2), wherein

brightness of said first image is directly proportional to energy intensity of said first ultrasound signal (U2), wherein said processing device (14) is configured to convert said first electrical signal (E1) into a second electrical signal (E2) according to a difference between said brightness of said first image and preset brightness, wherein said focused ultrasound transducers (18) are configured to receive said second electrical signal (E2) and use said second electrical signal (E2) to emit at least one third ultrasound signal (U3) whose energy intensity is larger than energy intensity of said first ultrasound signal (U1) to said target position which reflects said third ultrasound signal (U3) to form at least one fourth ultrasound signal (U4), wherein, after generating said third ultrasound signal (U3), said processing device (14) is configured to drive said focused ultrasound transducers (18) to start to receive said fourth ultrasound signal (U4) only during said preset period after said estimation period, wherein said processing device (14) is configured to use said display (16) to display a second image of said target position according to said fourth ultrasound signal (U4), wherein brightness of said second image is directly proportional to energy intensity of said third ultrasound signal (U3).

2. The display device for ultrasound energy according to claim 1, wherein said focused ultrasound transducers (18) are arranged into a two-dimension array or a concentric circle array.

3. The display device for ultrasound energy according to claim 1, wherein said first image is displayed according to first beamformed filtered data $rf(x_g,z_g)$, and said first beamformed filtered data $rf(x_g,z_g)$ satisfies following formulas:

$$\tilde{rf}(x_g, z_g) = F \times \sum_{n=1}^{N} \left(\sum_{n=1}^{N} \left((\hat{RF}_{M\times N})^T \times x_{M\times 1} \times \overline{TD_{1\times N}} \right) \right) \ ;$$

$$\begin{aligned} RF_{M\times N} \cong {} & \cos(2\pi f_r t) \times (chRF_{M\times N} + chRF_{M\times N}{}^*)/2 \\ & - \sin(2\pi f_r t) \times (-j) \times (chRF_{M\times N} + chRF_{M\times N}{}^*)/2 \end{aligned}$$

$$IQ_{m\times N} \cong [f_1(k), f_2(k), \ldots, f_i(k), \ldots, f_N(k)] \ ;$$

$$\begin{aligned} \hat{chRF}_{M\times N} \cong {} & [f_1(\frac{k}{f_{sIQ}} * f_{sRF}), f_2(\frac{k}{f_{sIQ}} * f_{sRF}), \ldots \\ & , f_i(\frac{k}{f_{sIQ}} * f_{sRF}), \ldots, f_N(\frac{k}{f_{sIQ}} * f_{sRF})] \end{aligned} \ ;$$

and

$$T_{M\times N} = x_{M\times 1} \times TD_{1\times N} \text{ ,}$$

wherein (x_g,z_g) is 3-D coordinate of said target position, and F is a first filtered factor, and N is the number of said focused ultrasound transducers (18), and n is an index of each of said focused ultrasound transducers (18), and $\hat{RF}_{M\times N}$ is a first beamformed data matrix with dimension $M\times N$, and t is time, and f_r is a first re-modulation frequency, and $\hat{chRF}_{M\times N}$ is a first channel data matrix with dimension $M\times N$, and $\hat{IQ}_{m\times N}$ is a matrix with dimension $m\times N$ of a baseband signal of said second ultrasound signal, and m is a natural number, and $f_i(k)$ is a column function of a i-th column of $\hat{IQ}_{m\times N}$, and k and i are natural numbers, and k = 1,2,...,m, and i = 1,2,...,N, and f_{sIQ} is a sampling frequency of $\hat{IQ}_{m\times N}$, and f_{sRF} is a resampled frequency of $\hat{IQ}_{m\times N}$, and $\overline{TD_{1\times N}}$ is a first time matrix of said second ultrasound signal moving from said target position to N pieces of said focused ultrasound transducers (18), and $T_{M\times N}$ is a matrix with dimension $M\times N$ comprising elements 0 and 1, and M is a natural number larger than a largest element of said first time matrix, and $x_{M\times 1}$ is a vector with dimension $M\times 1$, and $\hat{chRF}_{M\times N}{}^*$ is a conjugation of $\hat{chRF}_{M\times N}$, and said estimation period equals a distance between said target position and the focused ultrasound transducer (18) most distal from said target position multiplied by 2 and divided by said sound-traveling speed.

4. The display device for ultrasound energy according to claim 1, wherein said second image is displayed according to second beamformed filtered data $\tilde{rf}(x_g,z_g)'$, and said second beamformed filtered data $\tilde{rf}(x_g,z_g)'$ satisfies following formulas:

$$\tilde{rf}(x_g,z_g)' = F'\times\sum\nolimits_{n=1}^{N}\left(\sum\nolimits_{n=1}^{N}\left((\hat{RF}'_{M'\times N})^T \times x'_{M'\times 1}\times\overline{TD'_{1\times N}}\right)\right)\ ;$$

$$\begin{aligned}\hat{RF}'_{M'\times N} \cong{} & \cos(2\pi f_r' t)\times(\hat{chRF}'_{M'\times N} + \hat{chRF}'_{M'\times N}{}^*)/2 \\ & -\sin(2\pi f_r' t)\times(-j)\times(\hat{chRF}'_{M'\times N} + \hat{chRF}'_{M'\times N}{}^*)/2\end{aligned}\ ;$$

$$\hat{IQ}'_{m\times N} \cong [f_1'(k), f_2'(k),\ldots,f_i'(k),\ldots,f_N'(k)]\ ;$$

$$\begin{aligned}\hat{chRF}'_{M'\times N} \cong{} & [f_1'(\frac{k}{f_{sIQ}'}*f_{sRF}'), f_2'(\frac{k}{f_{sIQ}'}*f_{sRF}'),\ldots \\ & ,f_i'(\frac{k}{f_{sIQ}'}*f_{sRF}'),\ldots,f_N'(\frac{k}{f_{sIQ}'}*f_{sRF}')]\end{aligned}\ ;$$

and

$$T'_{M'\times N} = x'_{M'\times 1} \times \overline{TD'_{1\times N}} \ ,$$

wherein (x_g,z_g) is 3-D coordinate of said target position, and F' is a second filtered factor, and N is the number of said focused ultrasound transducers (18), and n is an index of each of said focused ultrasound transducers (18), and $\hat{RF}'_{M'\times N}$ is a second beamformed data matrix with dimension $M'\times N$, and t is time, and f_r' is a second remodulation frequency, and $\hat{chRF}'_{M'\times N}$ is a second channel data matrix with dimension $M'\times N$, and $\hat{IQ}'_{m\times N}$ is a matrix with dimension $m\times N$ of a baseband signal of said fourth ultrasound signal, and m is a natural number, and $f_i'(k)$ is a column function of a i-th column of $\hat{IQ}'_{m\times N}$, and k and i are natural numbers, and k = 1,2,...,m, and i = 1,2,...,N, and f_{sIQ}' is a sampling frequency of $IQ'_{m\times N}$, and f_{sRF}' is a resampled frequency of $IQ'_{m\times N}$, and $\overline{TD'_{1\times N}}$ is a second time matrix of said fourth ultrasound signal moving from said target position to N pieces of said focused ultrasound transducers (18), and $T_{M\times N}$ is a matrix with dimension $M'\times N$ comprising elements 0 and 1, and M' is a natural number larger than a largest element of said second time matrix, and $x'_{M'\times 1}$ is a vector with dimension $M'\times 1$, and $chRF'_{M'\times N}{}^*$ is a conjugation of $\hat{chRF}'_{M'\times N}$, and said estimation period equals a distance between said target position and the focused ultrasound transducer (18) most distal from said target position multiplied by 2 and divided by said sound-traveling speed.

5. A display device for ultrasound energy comprising:

a focused ultrasound emitting and receiving device (10) for emitting at least one first ultrasound signal (U1) to a target position of an organism (17), wherein said target position reflects said first ultrasound signal (U1) to form at least one second ultrasound signal (U2);
a processing device (14) connected with said focused ultrasound emitting and receiving device (10) for setting an estimation period according to a distance between said focused ultrasound emitting and receiving device (10) and said target position and sound-traveling speed, wherein said processing device (14) is configured to generate a first electrical signal (E1) and transmit said first electrical signal (E1) to said focused ultrasound emitting and receiving device (10) to control said focused ultrasound emitting and receiving device (10) to emit said first ultrasound signal (U1), wherein then said processing device (14) is configured to drive said focused ultrasound emitting and receiving device (10) to start to receive said second ultrasound signal (U2) only during a preset period after said estimation period, wherein said preset period is equal to or larger than response time of said focused ultrasound emitting and receiving device (10),
wherein said focused ultrasound emitting and receiving device (10) further comprises at least one focused ultrasound emitter (20) and at least one focused ultrasound receiver (22) connected with said processing device (14), wherein said focused ultrasound emitter (20) is surrounded by said focused ultrasound receiver (22), wherein said focused ultrasound emitter (20) is configured to receive said first electrical signal (E1) and generate said first ultrasound signal (U1) according to said first electrical signal (E1), wherein said processing device (14) is configured to drive said focused ultrasound receiver (22) to receive said second ultrasound signal (U2), wherein said preset period is equal to or larger than response time of said focused ultrasound receiver (22), wherein
a display (16) is connected with said processing device (14), **characterised in that** said processing device (14) is configured to use said display (16) to display a first image of said target position according to said second ultrasound signal (U2), wherein brightness of said first image is directly proportional to energy intensity of said first ultrasound signal (U2),
wherein said processing device (14) is configured to convert said first electrical signal (E1) into a second electrical signal (E2) according to a difference between said brightness of said first image and preset brightness, wherein said focused ultrasound receiver (22) is configured to receive said second electrical signal (E2), wherein said focused ultrasound emitter (20) is configured to use said second electrical signal (E2) to emit at least one third ultrasound signal (U3) whose energy intensity is larger than energy intensity of said first ultrasound signal (U1)

to said target position which reflects said third ultrasound signal (U3) to form at least one fourth ultrasound signal (U4), wherein, after generating said third ultrasound signal (U3), said processing device (14) is configured to drive said focused ultrasound receiver (22) to start to receive said fourth ultrasound signal (U4) only during said preset period after said estimation period, wherein said processing device (14) is configured to use said display (16) to display a second image of said target position according to said fourth ultrasound signal (U4), wherein

brightness of said second image is directly proportional to energy intensity of said third ultrasound signal (U3).

6. The display device for ultrasound energy according to claim 5, wherein said at least one focused ultrasound emitter (20) is a plurality of focused ultrasound emitters (20) arranged into a strip array with one dimension, and the number of said focused ultrasound receiver (22) is one, and said focused ultrasound emitters (20) and said focused ultrasound receiver (22) are arranged on a curved surface.

7. The display device for ultrasound energy according to claim 5, wherein said at least one focused ultrasound receiver (22) is a plurality of focused ultrasound receivers (22) arranged into a ring array, and the number of said focused ultrasound emitter (20) is one, and said focused ultrasound receivers (22) and said focused ultrasound emitter (20) are arranged on a curved surface.

8. The display device for ultrasound energy according to claim 5, wherein said first image is displayed according to first beamformed filtered data $\tilde{rf}(x_g,z_g)$, and said first beamformed filtered data $\tilde{rf}(x_g,z_g)$ satisfies following formulas:

$$\tilde{rf}(x_g,z_g)=F\times\sum\nolimits_{n=1}^{N}\left(\sum\nolimits_{n=1}^{N}\left(\left(\hat{RF}_{M\times N}\right)^{T}\times x_{M\times 1}\times\overline{TD_{1\times N}}\right)\right)\ ;$$

$$\begin{aligned}\hat{RF}_{M\times N} \cong{}& \cos(2\pi f_r t)\times(ch\hat{RF}_{M\times N}+ch\hat{RF}_{M\times N}{}^{*})/2\\ &-\sin(2\pi f_r t)\times(-j)\times(ch\hat{RF}_{M\times N}+ch\hat{RF}_{M\times N}{}^{*})/2\end{aligned}\ ;$$

$$\hat{IQ}_{m\times N}\cong[f_1(k),f_2(k),\ldots,f_i(k),\ldots,f_N(k)]\ ;$$

$$\begin{aligned}ch\hat{RF}_{M\times N}\cong{}&[f_1(\frac{k}{f_{sIQ}}*f_{sRF}),f_2(\frac{k}{f_{sIQ}}*f_{sRF}),\ldots\\ &,f_i(\frac{k}{f_{sIQ}}*f_{sRF}),\ldots,f_N(\frac{k}{f_{sIQ}}*f_{sRF})]\end{aligned}\ ;$$

and

$$T_{M\times N}=x_{M\times 1}\times\overline{TD_{1\times N}}\ ,$$

wherein (x_g,z_g) is 3-D coordinate of said target position, and F is a first filtered factor, and N is the number of said focused ultrasound receiver, and n is an index of each said focused ultrasound receiver, and $\hat{RF}_{M\times N}$ is a first beamformed data matrix with dimension $M\times N$, and t is time, and f_r is a first re-modulation frequency, and

$\widehat{chRF}_{M\times N}$ is a first channel data matrix with dimension $M\times N$, and $\widehat{IQ}_{m\times N}$ is a matrix with dimension $m\times N$ of a baseband signal of said second ultrasound signal, and m is a natural number, and $f_i(k)$ is a column function of a i-th column of $\widehat{IQ}_{m\times N}$, and k and i are natural numbers, and k = 1,2, ..., m, and i = 1,2,...,N, and f_{sIQ} is a sampling frequency of $\widehat{IQ}_{m\times N}$, and f_{sRF} is a resampled frequency of $\widehat{IQ}_{m\times N}$, and $\overline{TD_{1\times N}}$ is a first time matrix of said second ultrasound signal moving from said target position to N pieces of said focused ultrasound receivers, and $T_{M\times N}$ is a mask-operated matrix with dimension $M\times N$ comprising elements 0 and 1, and M is a natural number larger than a largest element of said first time matrix, and $x_{M\times 1}$ is a vector with dimension $M\times 1$, and $\widehat{chRF}_{M\times N}^{*}$ is a conjugation of $\widehat{chRF}_{M\times N}$, and said estimation period equals a distance between said target position and said focused ultrasound receiver (22) most distal from said target position multiplied by 2 and divided by said sound-traveling speed.

9. The display device for ultrasound energy according to claim 5, wherein said second image is displayed according to second beamformed filtered data $\widetilde{rf}(x_g,z_g)'$, and said second beamformed filtered data $\widetilde{rf}(x_g,z_g)'$ satisfies following formulas:

$$\widetilde{rf}(x_g,z_g)' = F'\times\sum_{n=1}^{N}\left(\sum_{n=1}^{N}\left((\widehat{RF}'_{M'\times N})^{T}\times x'_{M'\times 1}\times\overline{TD'_{1\times N}}\right)\right) ;$$

$$\begin{aligned}\widehat{RF}'_{M'\times N} \cong{} & \cos(2\pi f_r' t)\times(\widehat{chRF}'_{M'\times N}+\widehat{chRF}'^{*}_{M'\times N})/2 \\ & -\sin(2\pi f_r' t)\times(-j)\times(\widehat{chRF}'_{M'\times N}+\widehat{chRF}'^{*}_{M'\times N})/2\end{aligned} ;$$

$$\widehat{IQ}'_{m'\times N} \cong [f_1'(k), f_2'(k),\ldots,f_i'(k),\ldots,f_N'(k)] ;$$

$$\begin{aligned}\widehat{chRF}'_{M'\times N} \cong{} & [f_1'(\frac{k}{f_{sIQ}'}*f_{sRF}'), f_2'(\frac{k}{f_{sIQ}'}*f_{sRF}'),\ldots, f_i'(\frac{k}{f_{sIQ}'}*f_{sRF}'), \\ & \ldots, f_N'(\frac{k}{f_{sIQ}'}*f_{sRF}')]\end{aligned} ;$$

and

$$T'_{M'\times N} = x'_{M'\times 1}\times\overline{TD'_{1\times N}} ,$$

wherein (x_g,z_g) is 3-D coordinate of said target position, and F' is a second filtered factor, and N is the number of said focused ultrasound receiver, and n is an index of each said focused ultrasound receiver, and $\widehat{RF}'_{M'\times N}$ is a second beamformed data matrix with dimension $M'\times N$, and t is time, and f_r' is a second re-modulation frequency, and $\hat{chRF}'_{M'\times N}$ is a second channel data matrix with dimension $M'\times N$, and $\hat{IQ}'_{m\times N}$ is a matrix with dimension $m\times N$ of a baseband signal of said fourth ultrasound signal, and m is a natural number, and $f_i'(k)$ is a column function of a i-th column of $\hat{IQ}'_{m\times N}$, and k and i are natural numbers, and k = 1,2,...,m, and i = 1,2,...,N, and f_{sIQ}' is a sampling frequency of $\hat{IQ}'_{m\times N}$, and f_{sRF}' is a resampled frequency of $\hat{IQ}'_{m\times N}$, and $\overline{\mathrm{TD}'}_{1\times N}$ is a second time matrix of said fourth ultrasound signal moving from said target position to N pieces of said focused ultrasound receivers, and $T_{M\times N}$ is a matrix with dimension $M'\times N$ comprising elements 0 and 1, and M' is a natural number larger than a largest element of said second time matrix, and $x'_{M'\times 1}$ is a vector with dimension $M'\times 1$, and $\hat{chRF}'^{*}_{M'\times N}$ is a conjugation of $chRF'_{M'\times N}$, and said estimation period equals a distance between said target position and said focused ultrasound receiver (22) most distal from said target position multiplied by 2 and divided by said sound-traveling speed.

10. The display device for ultrasound energy according to claims 1 or 5, wherein said third ultrasound signal (U3) and said fourth ultrasound signal (U4) are burst waves.

11. The display device for ultrasound energy according to claim 10, wherein said first ultrasound signal (U1) and said second ultrasound signal (U2) are burst waves.

12. The display device for ultrasound energy according to claim 10, wherein said first ultrasound signal (U1) and said third ultrasound signal (U3) are configured to penetrate through cranial bone to reach said target position, and the frequency of said first ultrasound signal (U1) and said third ultrasound signal (U3) is inversely proportional to thickness of said cranial bone.

13. The display device for ultrasound energy according to claims 1 or 5 configured for said organism (17) being a central nervous system (CNS) tissue having capillaries containing blood-brain barrier.

Patentansprüche

1. Anzeigevorrichtung für Ultraschallenergie, umfassend:

eine Vorrichtung zum Emittieren und Empfangen von fokussiertem Ultraschall (10) zum Emittieren zumindest eines ersten Ultraschallsignals (U1) auf eine Zielposition eines Organismus (17), wobei die Zielposition das erste Ultraschallsignal (U1) reflektiert, um zumindest ein zweites Ultraschallsignal (U2) zu erzeugen,
eine Verarbeitungsvorrichtung (14), die mit der Vorrichtung zum Emittieren und
Empfangen von fokussiertem Ultraschall (10) verbunden ist, um eine Schätzdauer gemäß einer Distanz zwischen der Vorrichtung zum Emittieren und Empfangen von fokussiertem Ultraschall (10) und der Zielposition und der Schallgeschwindigkeit einzustellen, wobei die Verarbeitungsvorrichtung (14) darauf ausgelegt ist, ein erstes elektrisches Signal (E1) zu erzeugen und das erste elektrische Signal (E1) zu der Vorrichtung zum Emittieren und Empfangen von fokussiertem Ultraschall (10) zu übermitteln, um die Vorrichtung zum Emittieren und
Empfangen von fokussiertem Ultraschall (10) zu steuern, um das erste Ultraschallsignal (U1) zu emittieren, wobei dann die Verarbeitungsvorrichtung (14) darauf ausgelegt ist, die Vorrichtung zum Emittieren und Empfangen von fokussiertem Ultraschall (10) anzutreiben, anzufangen, nur während einer festgelegten Dauer nach der Schätzdauer das zweite Ultraschallsignal (U2) zu empfangen,
wobei die festgelegte Dauer gleich oder größer als die Antwortzeit der Vorrichtung zum Emittieren und Empfangen fokussierten Ultraschalls (10) ist,
wobei die Vorrichtung zum Emittieren und Empfangen von fokussiertem Ultraschall (10) ferner eine Vielzahl an Wandlern für fokussierten Ultraschall (18) umfasst, um das erste elektrische Signal (E1) zu empfangen, um das erste Ultraschallsignal (U1) gemäß zu dem ersten elektrischen Signal (E1) zu erzeugen, wobei die Verar-

beitungsvorrichtung (14) darauf ausgelegt ist, die Wandler für fokussierten Ultraschall (18) anzutreiben, das zweite Ultraschallsignal (U2) zu empfangen, wobei die festgelegte Dauer gleich oder größer als die Antwortzeit der Wandler für fokussierten Ultraschall (18) ist, wobei eine Anzeige (16) mit der Verarbeitungsvorrichtung (14) verbunden ist,
dadurch gekennzeichnet, dass
die Verarbeitungsvorrichtung (14) darauf ausgelegt ist, die Anzeige (16) zu verwenden, um ein erstes Bild der Zielposition gemäß dem zweiten Ultraschallsignal (U2) anzuzeigen,
wobei die Helligkeit des ersten Bildes direkt proportional zu der Energieintensität des ersten Ultraschallsignals (U2) ist,
wobei die Verarbeitungsvorrichtung (14) darauf ausgelegt ist, das erste elektrische Signal (E1) in ein zweiten elektrisches Signal (E2) gemäß einer Differenz zwischen der Helligkeit des ersten Bildes und der voreingestellten Helligkeit umzuwandeln,
wobei die Wandler für fokussierten Ultraschall (18) darauf ausgelegt sind, das zweite elektrische Signal (E2) zu empfangen und das zweite elektrische Signal (E2) zu verwenden, um zumindest ein drittes Ultraschallsignal (U3), dessen Energieintensität größer ist als die Energieintensität des ersten Ultraschallsignals (U1), auf die Zielposition zu emittieren, die das dritte Ultraschallsignal (U3) reflektiert, um zumindest ein viertes Ultraschallsignal (U4) zu erzeugen, wobei, nach dem Erzeugen des dritten Ultraschallsignals (U3), die Verarbeitungsvorrichtung (14) darauf ausgelegt ist, die Wandler für fokussierten Ultraschall (18) anzutreiben, nur während der vorher bestimmten Dauer nach der Schätzdauer, damit anzufangen, das vierte Ultraschallsignal (U4) zu empfangen, wobei die Verarbeitungsvorrichtung (14) darauf ausgelegt ist, die Anzeige (16) zu verwenden, ein zweites Bild der Zielposition gemäß dem vierten Ultraschallsignal (U4) anzuzeigen, wobei die Helligkeit des zweiten Bildes direkt proportional zu der Energieintensität des dritten Ultraschallsignals (U3) ist.

2. Anzeigevorrichtung für Ultraschallenergie gemäß Anspruch 1, bei der die Wandler für fokussierten Ultraschall (18) in einer zwei-Dimensionen-Anordnung oder einer konzentrischen Kreisanordnung angeordnet sind.

3. Anzeigevorrichtung für Ultraschallenergie gemäß Anspruch 1, bei der das erste Bild gemäß ersten strahlgeformten gefilterten Daten $rf(x_g,z_g)$ angezeigt wird und die ersten strahlgeformten gefilterten Daten $rf(x_g,z_g)$ erfüllen folgende Formeln:

$$\widetilde{rf}\left(x_g,z_g\right)=F\times\sum_{n=1}^{N}\left(\sum_{n=1}^{N}\left(\left(\widehat{RF}_{M\times N}\right)^T\times x_{M\times 1}\times\overline{TD_{1\times N}}\right)\right)\ ;$$

$$RF_{M\times N}\cong\cos(2\pi f_r t)\times(chRF_{M\times N}+chRF_{M\times N}{}^{*})/2-\sin(2\pi f_r t)\times(-j)\times$$
$$(chRF_{M\times N}+chRF_{M\times N}{}^{*})/2\ ;$$

$$IQ_{m\times N}\cong[f_1(k),f_2(k),\dots,f_i(k),\dots,f_N(k)]\ ;$$

$$ch\widehat{RF}_{M\times N}\cong\left[f_1\left(\frac{k}{f_{sIQ}}*f_{sRF}\right),f_2\left(\frac{k}{f_{sIQ}}*f_{sRF}\right),\dots,f_i\left(\frac{k}{f_{sIQ}}*f_{sRF}\right),\dots,f_N\left(\frac{k}{f_{sIQ}}*f_{sRF}\right)\right]\ ;$$

und

$$T_{M\times N}=x_{M\times 1}\times TD_{1\times N}\ ,$$

wobei (x_g,z_g) eine 3-D Koordinate der Zielposition ist und F ist ein erster gefilterter Faktor und N die Anzahl der Wandler für fokussierten Ultraschall (18) ist und n ein Index von jedem der Wandler für fokussierten Ultraschall (18) ist und $\widehat{\mathrm{RF}}_{M\times N}$ eine erste strahlgeformte Datenmatrix mit Dimension $M \times N$ ist und t die Zeit ist und f_r eine erste Ummodulationsfrequenz ist und $ch\widehat{RF}_{M\times N}$ eine erste Kanaldatenmatrix mit Dimension $M \times N$ ist und $\widehat{IQ}_{m\times N}$ eine Matrix mit Dimension $m \times N$ eines Basisbandsignals des zweiten Ultraschallsignals ist und m eine natürliche

Zahl ist und $f_i(k)$ eine Spaltenfunktion einer i-ten Spalte von $\widehat{IQ}_{m\times N}$ ist und k und i natürliche Zahlen sind und k = 1,2,...,m und i = 1,2,...,N und f_{sIQ} eine Abtastfrequenz von $\widehat{IQ}_{m\times N}$ ist und f_{sRF} eine neu abgetastete Frequenz von $\widehat{IQ}_{m\times N}$ ist und $\overline{\mathrm{TD}_{1\times N}}$ eine Matrix einer ersten Zeit des zweiten Ultraschallsignals ist, das sich von der Zielposition zu N Teilen der Wandler für fokussierten Ultraschall (18) bewegt und $T_{M\times N}$ eine Matrix mit Dimension $M \times N$ ist, die Elemente 0 und 1 umfasst und M eine natürliche Zahl ist, die größer als ein größtes Element der Matrix einer ersten Zeit ist und $x_{M\times 1}$ ein Vektor mit Dimension $M \times 1$ ist und $ch\widehat{RF}_{M\times N}^{\;*}$ eine Konjugation von $ch\widehat{RF}_{M\times N}$ ist und der Schätzzeitraum einer Distanz zwischen der Zielposition und dem Wandler für fokussierten Ultraschall (18), der am entferntesten zu der Zielposition ist, multipliziert mit 2 und durch die Schallgeschwindigkeit dividiert entspricht.

4. Anzeigevorrichtung für Ultraschallenergie gemäß Anspruch 1, bei der das zweite Bild gemäß zweiten strahlgeformten gefilterten Daten $\widetilde{rf}(x_g,z_g)'$ angezeigt wird und die zweiten strahlgeformten Daten $\widetilde{rf}(x_g,z_g)'$ die folgenden Gleichungen erfüllen:

$$\widetilde{rf}(x_g,z_g)' = F' \times \textstyle\sum_{n=1}^{N}\left(\sum_{n=1}^{N}\left(\left(\widehat{RF}'_{M'\times N}\right)^{T} \times x'_{M'\times 1} \times \overline{TD'_{1\times N}}\right)\right) \;;$$

$$\widehat{RF}'_{M'\times N} \cong \cos(2\pi f_r' t) \times \left(ch\widehat{RF}'_{M'\times N} + ch\widehat{RF}'^{\,*}_{M'\times N}\right)/2 - \sin(2\pi f_r' t) \times (-j) \times \left(ch\widehat{RF}'_{M'\times N} + ch\widehat{RF}'^{\,*}_{M'\times N}\right)/2 \;;$$

$$\widehat{IQ}'_{m\times N} \cong [f_1'(k), f_2'(k), \ldots, f_i'(k), \ldots, f_N'(k)] \;;$$

$$ch\widehat{RF}'_{M'\times N} \cong \left[f_1'\left(\frac{k}{f'_{sIQ}} * f'_{sRF}\right), f_2'\left(\frac{k}{f'_{sIQ}} * f'_{sRF}\right), \ldots, f_i'\left(\frac{k}{f'_{sIQ}} * f'_{sRF}\right), \ldots, f_N'\left(\frac{k}{f'_{sIQ}} * f'_{sRF}\right)\right] \;;$$

und

$$T'_{M\times N} = x'_{M'\times 1} \times \overline{TD'_{1\times N}} \;;$$

wobei (x_g,z_g) eine 3-D Koordinate der Zielposition ist und F' ein zweiter gefilterter Faktor ist und N die Anzahl der Wandler für fokussierten Ultraschall (18) ist und n ein Index von jedem der Wandler für fokussierten Ultraschall (18) ist und $\widehat{RF}'_{M'\times N}$ eine zweite strahlgeformte Datenmatrix mit Dimension $M' \times N$ ist und t die Zeit ist und f_r' eine zweite Ummodulationsfrequenz ist und $ch\widehat{RF}'_{M'\times N}$ eine zweite Kanaldatenmatrix mit Dimension $M' \times N$ ist und $\widehat{IQ}'_{m\times N}$ eine Matrix mit Dimension $m \times N$ eines Basisbandsignals des vierten Ultraschallsignals ist und m eine natürliche Zahl ist und $\mathrm{f}_\mathrm{i}'(\mathrm{k})$ eine Spaltenfunktion einer i-ten Spalte von $\widehat{IQ}'_{m\times N}$ ist und k und i natürliche Zahlen sind und k = 1,2,...,m und i = 1,2,...,N und f'_{sIQ} eine Abtastfrequenz von $\widehat{IQ}'_{m\times N}$ ist und f'_{sRF} eine neu abgetastete

Frequenz von $\widehat{IQ}'_{m\times N}$ ist und $\overline{TD'_{1\times N}}$ eine Matrix einer zweiten Zeit des vierten Ultraschallsignals ist, das sich von der Zielposition zu *N* Teilen der Wandler für fokussierten Ultraschall (18) bewegt und $T'_{M\times N}$ eine Matrix mit Dimension *M'* × *N* ist, die die Elemente 0 und 1 umfasst und *M'* natürliche Zahl ist, die größer als ein größtes Element der Matrix einer zweiten Zeit ist und $x'_{M'\times 1}$ ein Vektor mit Dimension *M'* × 1 ist und $\widehat{chRF}'^{*}_{M'\times N}$ eine Konjuga-tion von $\widehat{chRF}'_{M'\times N}$ ist und der Schätzzeitraum einer Distanz zwischen der Zielposition und dem Wandler für fokussierten Ultraschall (18), der am entferntesten zu der Zielposition ist, multipliziert mit 2 und durch die Schallgeschwindigkeit geteilt entspricht.

5. Anzeigevorrichtung für Ultraschallenergie, umfassend:

eine Vorrichtung zum Emittieren und Empfangen von fokussiertem Ultraschall (10) zum Emittieren zumindest eines ersten Ultraschallsignals (U1) auf eine Zielposition eines Organismus (17), wobei die Zielposition das erste Ultraschallsignal (U1) reflektiert, um zumindest ein zweites Ultraschallsignal (U2) zu erzeugen, eine Verarbeitungsvorrichtung (14), die mit der Vorrichtung zum Emittieren und Empfangen von fokussiertem Ultraschall (10) verbunden ist, um einen Schätzzeitraum gemäß einer Distanz zwischen der Vorrichtung zum Emittieren und Empfangen von fokussiertem Ultraschall (10) und der Zielposition und der Schallgeschwindigkeit einzustellen, wobei die Verarbeitungsvorrichtung (14) darauf ausgelegt ist, ein erstes elektrisches Signal (E1) zu erzeugen und das erste elektrische Signal (E1) zu der fokussierten Vorrichtung zum Emittieren und Empfangen von Ultraschall (10) zu übermitteln, um die Vorrichtung zum Emittieren und Empfangen von fokussiertem Ultraschall (10) zu steuern, um das erste Ultraschallsignal (U1) zu emittieren, wobei dann die Verarbeitungsvorrichtung (14) darauf ausgelegt ist, die fokussierte Vorrichtung zum Emittieren und Empfangen von Ultraschall (10) anzutreiben, anzufangen, nur während einer festgelegten Dauer nach dem Schätzzeitraum, das zweite Ultraschallsignal (U2) zu empfangen, wobei die festgelegte Dauer gleich oder größer als die Antwortzeit der Vorrichtung zum Emittieren und Empfangen fokussierten Ultraschalls (10) ist, wobei die Vorrichtung zum Emittieren und Empfangen von fokussiertem Ultraschall (10) ferner zumindest einen Emitter für fokussierten Ultraschall (20) umfasst und zumindest einen Empfänger für fokussierten Ultraschall (22), der mit der Verarbeitungsvorrichtung (14) verbunden ist, wobei der Emitter für fokussierten Ultraschall (20) von dem Empfänger für fokussierten Ultraschall (22) umgeben ist, wobei der Emitter für fokussierten Ultraschall (20) darauf ausgelegt ist, das erste elektrische Signal (E1) zu empfangen und das erste Ultraschallsignal (U1) gemäß dem ersten elektrischen Signal (E1) zu erzeugen, wobei die Verarbeitungsvorrichtung (14) darauf ausgelegt ist, den Empfänger für fokussierten Ultraschall (22) anzutreiben, das zweite Ultraschallsignal (U2) zu empfangen, wobei die festgelegte Dauer gleich oder größer als die Antwortzeit des Empfängers für fokussierten Ultraschall (22) ist, wobei eine Anzeige (16) mit der Verarbeitungsvorrichtung (14) verbunden ist,

dadurch gekennzeichnet, dass

die Verarbeitungsvorrichtung (14) darauf ausgelegt ist, die Anzeige (16) zu verwenden, um ein erstes Bild der Zielposition gemäß dem zweiten Ultraschallsignal (U2) anzuzeigen,

wobei die Helligkeit des ersten Bildes direkt proportional zu der Energieintensität des ersten Ultraschallsignals (U2) ist,

wobei die Verarbeitungsvorrichtung (14) darauf ausgelegt ist, das erste elektrische Signal (E1) in ein zweiten elektrisches Signal (E2) gemäß einer Differenz zwischen der Helligkeit des ersten Bildes und der voreingestellten Helligkeit umzuwandeln,

wobei der Empfänger für fokussierten Ultraschall (22) darauf ausgelegt ist, das zweite elektrische Signal (E2) zu empfangen, wobei der Emitter für fokussierten Ultraschall (20) darauf ausgelegt ist, das zweite elektrische Signal (E2) zu verwenden, um zumindest ein drittes Ultraschallsignal (U3), dessen Energieintensität größer ist als die Energieintensität des ersten Ultraschallsignals (U1), auf die Zielposition zu emittieren, die das dritte Ultraschallsignal (U3) reflektiert, um zumindest ein viertes Ultraschallsignal (U4) zu erzeugen, wobei nach dem Erzeugen des dritten Ultraschallsignals (U3) die Verarbeitungsvorrichtung (14) darauf ausgelegt ist, den Empfänger für fokussierten Ultraschall (22) anzutreiben, damit anzufangen, das vierte Ultraschallsignal (U4) nur während der festgelegten Dauer nach dem Schätzzeitraum zu empfangen, wobei die Verarbeitungsvorrichtung (14) darauf ausgelegt ist, die Anzeige (16) zu verwenden, um ein zweites Bild der Zielposition gemäß dem vierten Ultraschallsignal (U4) anzuzeigen, wobei die Helligkeit des zweiten Bildes direkt proportional zu der Energieintensität des dritten Ultraschallsignals (U3) ist.

6. Anzeigevorrichtung für Ultraschallenergie gemäß Anspruch 5, bei der der zumindest eine Emitter für fokussierten Ultraschall (20) eine Vielzahl an Emittern für fokussierten Ultraschall (20) ist, die in einer Reihenanordnung mit einer Dimension angeordnet sind und die Anzahl der Empfänger für fokussierten Ultraschall (22) eins ist und die Emitter für fokussierten Ultraschall (20) und der Empfänger für fokussierten Ultraschall (22) an einer gekrümmten Oberfläche angeordnet sind.

7. Anzeigevorrichtung für Ultraschallenergie gemäß Anspruch 5, bei der der zumindest eine Empfänger für fokussierten Ultraschall (22) eine Vielzahl an Empfängern für fokussierten Ultraschall (22) ist, die in einer Ringanordnung angeordnet sind und die Anzahl der Emitter für fokussierten Ultraschall (20) ist eins und die Empfänger für fokussierten Ultraschall (22) und der Emitter für fokussierten Ultraschall (20) sind an einer gekrümmten Oberfläche angeordnet.

8. Anzeigevorrichtung für Ultraschallenergie gemäß Anspruch 5, bei der das erste Bild gemäß ersten strahlgeformten gefilterten Daten $\widetilde{rf}(x_g, z_g)$ angezeigt wird und die ersten strahlgeformten Daten $\widetilde{rf}(x_g, z_g)$ erfüllen die folgenden Gleichungen:

$$\widetilde{rf}(x_g, z_g) = F \times \sum_{n=1}^{N} \left(\sum_{n=1}^{N} \left(\left(\widehat{RF}_{M\times N} \right)^T \times x_{M\times 1} \times \overline{TD_{1\times N}} \right) \right) \;;$$

$$\widehat{RF}_{M\times N} \cong \cos(2\pi f_r t) \times \left(ch\widehat{RF}_{M\times N} + ch\widehat{RF}_{M\times N}{}^{*} \right)/2 - \sin(2\pi f_r t) \times (-j) \times$$
$$\left(ch\widehat{RF}_{M\times N} + ch\widehat{RF}_{M\times N}{}^{*} \right)/2 \;;$$

$$IQ_{m\times N} \cong [f_1(k), f_2(k), \ldots, f_i(k), \ldots, f_N(k)] \;;$$

$$ch\widehat{RF}_{M\times N} \cong \left[f_1\left(\frac{k}{f_{sIQ}} * f_{sRF}\right), f_2\left(\frac{k}{f_{sIQ}} * f_{sRF}\right), \ldots, f_i\left(\frac{k}{f_{sIQ}} * f_{sRF}\right), \ldots, f_N\left(\frac{k}{f_{sIQ}} * f_{sRF}\right) \right] \;;$$

und

$$T_{M\times N} = x_{M\times 1} \times TD_{1\times N} \;,$$

wobei (x_g, z_g) eine 3-D Koordinate der Zielposition ist und F ist ein erster gefilterter Faktor und N ist die Anzahl der Empfänger für fokussierten Ultraschall und n ist ein Index von jedem der Empfänger für fokussierten Ultraschall und $\widehat{RF}_{M\times N}$ ist eine erste strahlgeformte Datenmatrix mit Dimension $M \times N$ und t ist die Zeit und f_r ist eine erste Ummodulationsfrequenz und $ch\widehat{RF}_{M\times N}$ ist eine erste Kanaldatenmatrix mit Dimension $M \times N$ und $\widehat{IQ}_{m\times N}$ ist eine Matrix mit Dimension $m \times N$ eines Basisbandsignals des zweiten Ultraschallsignals und m ist eine natürliche Zahl und $f_i(k)$ ist eine Spaltenfunktion einer i-ten Spalte von $\widehat{IQ}_{m\times N}$ und k und i sind natürliche Zahlen und k = 1,2,...,m und i = 1,2,...,N und f_{sIQ} ist eine Abtastfrequenz von $\widehat{IQ}_{m\times N}$ und f_{sRF} ist eine neu abgetastete Frequenz von $\widehat{IQ}_{m\times N}$ und $\overline{TD_{1\times N}}$ ist eine Matrix einer ersten Zeit des zweiten Ultraschallsignals, das sich von der Zielposition zu N Teilen der Empfänger für fokussierten Ultraschall bewegt und $T_{M\times N}$ ist eine mit Maskierung verwendete Matrix mit Dimension $M \times N$, die Elemente 0 und 1 umfasst und M ist eine natürliche Zahl, die größer ist als ein größtes Element der Matrix einer ersten Zeit und $x_{M\times 1}$ ist ein Vektor mit Dimension $M \times 1$ und $ch\widehat{RF}_{M\times N}{}^{*}$ ist eine Konjugation von $ch\widehat{RF}_{M\times N}$ und der Schätzzeitraum entspricht einer Distanz zwischen der Zielposition und dem

Empfänger für fokussierten Ultraschall (22), der am entferntesten zu der Zielposition ist, multipliziert mit 2 und durch die Schallgeschwindigkeit geteilt.

9. Anzeigevorrichtung für Ultraschallenergie gemäß Anspruch 5, bei der das zweite Bild gemäß zweiten strahlgeformten gefilterten $\widetilde{rf}(x_g, z_g)'$ angezeigt wird und die zweiten strahlgeformten Daten $\widetilde{rf}(x_g, z_g)'$ erfüllen die folgenden Gleichungen:

$$\widetilde{rf}(x_g, z_g)' = F' \times \sum_{n=1}^{N} \left(\sum_{n=1}^{N} \left(\left(\widehat{RF}'_{M' \times N} \right)^T \times x'_{M' \times 1} \times \overline{TD'_{1 \times N}} \right) \right) \; ;$$

$$\widehat{RF}'_{M' \times N} \cong \cos(2\pi f_r' t) \times \left(ch\widehat{RF}'_{M' \times N} + ch\widehat{RF}'^{*}_{M' \times N} \right)/2 - \sin(2\pi f_r' t) \times (-j) \times$$

$$\left(ch\widehat{RF}'_{M' \times N} + ch\widehat{RF}'^{*}_{M' \times N} \right)/2 \; ;$$

$$\widehat{IQ}'_{m \times N} \cong [f_1'(k), f_2'(k), \dots, f_i'(k), \dots, f_N'(k)] \; ;$$

$$ch\widehat{RF}'_{M' \times N} \cong \left[f_1' \left(\frac{k}{f'_{sIQ}} * f'_{sRF} \right), f_2' \left(\frac{k}{f'_{sIQ}} * f'_{sRF} \right), \dots, f_i' \left(\frac{k}{f'_{sIQ}} * f'_{sRF} \right), \dots, f_N' \left(\frac{k}{f'_{sIQ}} * f'_{sRF} \right) \right] \; ;$$

und

$$T'_{M \times N} = x'_{M' \times 1} \times \overline{TD'_{1 \times N}} \; ;$$

wobei (x_g, z_g) eine 3-D Koordinate der Zielposition ist und *F'* ist ein zweiter gefilterter Faktor und *N* ist die Anzahl der Empfänger für fokussierten Ultraschall und *n* ist ein Index von jedem der Empfänger für fokussierten Ultraschall und $\widehat{RF}'_{M' \times N}$ ist eine zweite strahlgeformte Datenmatrix mit Dimension *M'* × *N* und *t* ist die Zeit und f_r' ist eine zweite Ummodulationsfrequenz und $ch\widehat{RF}'_{M' \times N}$ ist eine zweite Kanaldatenmatrix mit Dimension *M'* × *N* und $\widehat{IQ}'_{m \times N}$ eine Matrix mit Dimension *m* × *N* eines Basisbandsignals des vierten Ultraschallsignals und m ist eine natürliche Zahl und $f_i'(k)$ ist eine Spaltenfunktion einer i-ten Spalte von $\widehat{IQ}'_{m \times N}$ und *k* und *i* sind natürliche Zahlen und *k* = 1,2,...,*m* und *i* = 1,2,...,*N* und f'_{sIQ} ist eine Abtastfrequenz von $\widehat{IQ}'_{m \times N}$ und f'_{sRF} ist eine neu abgetastete Frequenz von $\widehat{IQ}'_{m \times N}$ und $\overline{TD'_{1 \times N}}$ ist eine Matrix einer zweiten Zeit des vierten Ultraschallsignals, das sich von der Zielposition zu N Teilen der Empfänger für fokussierten Ultraschall bewegt und $T'_{M \times N}$ ist eine Matrix mit Dimension *M'* × *N* die Elemente 0 und 1 umfasst und *M'* ist eine natürliche Zahl, die größer ist als ein größtes Element der Matrix einer zweiten Zeit und $x'_{M' \times 1}$ ist ein Vektor mit Dimension *M'* × 1 und $ch\widehat{RF}'^{*}_{M' \times N}$ ist eine Konjugation von $ch\widehat{RF}'_{M' \times N}$ und der Schätzzeitraum einer Distanz zwischen der Zielposition und dem

Empfänger für fokussierten Ultraschall (22), der am entferntesten zu der Zielposition ist, multipliziert mit 2 und durch die Schallgeschwindigkeit geteilt entspricht.

10. Anzeigevorrichtung für Ultraschallenergie gemäß Ansprüchen 1 oder 5, bei der das dritte Ultraschallsignal (U3) und das vierte Ultraschallsignal (U4) Burst-Wellen sind.

11. Anzeigevorrichtung für Ultraschallenergie gemäß Anspruch 10, bei der das erste Ultraschallsignal (U1) und das zweite Ultraschallsignal (U2) Burst-Wellen sind.

12. Anzeigevorrichtung für Ultraschallenergie gemäß Anspruch 10, bei der das erste Ultraschallsignal (U1) und das dritte Ultraschallsignal (U3) darauf ausgelegt sind, durch den Schädelknochen zu dringen, um die Zielposition zu erreichen und die Frequenz des ersten Ultraschallsignals (U1) und des dritten Ultraschallsignals (U3) invers proportional zu der Dicke des Schädelknochens sind.

13. Anzeigevorrichtung für Ultraschallenergie gemäß Ansprüchen 1 oder 5, darauf ausgelegt, dass der Organismus (17) ein Gewebe eines zentralen Nervensystems (ZNS) ist, der Kapillaren aufweist, die die Blut-Hirn-Schranke umfassen.

Revendications

1. Dispositif d’affichage pour une énergie ultrasonore comprenant:

un dispositif d’émission et de réception d’ultrasons focalisés (10) pour émettre au moins un premier signal d’ultrasons (U1) à une position cible d’un organisme (17), dans lequel ladite position cible reflète ledit premier signal d’ultrasons (U1) pour former au moins un deuxième signal d’ultrasons (U2);
un dispositif de traitement (14) raccordé avec ledit dispositif d’émission et de réception d’ultrasons focalisés (10) pour définir une période d’estimation selon une distance entre ledit dispositif d’émission et de réception d’ultrasons focalisés (10) et ladite position cible et la vitesse du son, dans lequel ledit dispositif de traitement (14) est configuré pour générer un premier signal électrique (E1) et transmettre ledit premier signal électrique (E1) audit dispositif d’émission et de réception d’ultrasons focalisés (10) pour commander ledit dispositif d’émission et de réception d’ultrasons focalisés (10) pour émettre ledit premier signal d’ultrasons (U1), dans lequel ensuite ledit dispositif de traitement (14) est configuré pour entraîner ledit dispositif d’émission et de réception d’ultrasons focalisés (10) pour commencer à recevoir ledit deuxième signal d’ultrasons (U2) uniquement durant une période prédéfinie après ladite période d’estimation, dans lequel ladite période prédéfinie est égale ou supérieure à un temps de réponse dudit dispositif d’émission et de réception d’ultrasons focalisés (10);
dans lequel ledit dispositif d’émission et de réception d’ultrasons focalisés (10) comprend en outre une pluralité de transducteurs à ultrasons focalisés (18) pour recevoir ledit premier signal électrique (E1) pour générer ledit premier signal d’ultrasons (U1) selon ledit premier signal électrique (E1),
dans lequel ledit dispositif de traitement (14) est configuré pour entraîner lesdits transducteurs à ultrasons focalisés (18) pour recevoir ledit deuxième signal d’ultrasons (U2), dans lequel ladite période prédéfinie est égale ou supérieure à un temps de réponse desdits transducteurs à ultrasons focalisés (18),
dans lequel un affichage (16) est raccordé avec ledit dispositif de traitement (14), **caractérisé en ce que** ledit dispositif de traitement (14) est configuré pour utiliser ledit affichage (16) pour afficher une première image de ladite position cible selon ledit deuxième signal d’ultrasons (U2),
dans lequel une luminosité de ladite première image est directement proportionnelle à l’intensité d’énergie dudit premier signal d’ultrasons (U2), dans lequel ledit dispositif de traitement (14) est configuré pour convertir ledit premier signal électrique (E1) en un second signal électrique (E2) selon une différence entre ladite luminosité de ladite première image et une luminosité prédéfinie,
dans lequel lesdits transducteurs à ultrasons focalisés (18) sont configurés pour recevoir ledit second signal électrique (E2) et utiliser ledit second signal électrique (E2) pour émettre au moins un troisième signal d’ultrasons (U3) dont l’intensité d’énergie est supérieure à l’intensité d’énergie dudit premier signal d’ultrasons (U1) à ladite position cible qui reflète ledit troisième signal d’ultrasons (U3) pour former au moins un quatrième signal d’ultrasons (U4),
dans lequel, après avoir généré ledit troisième signal d’ultrasons (U3), ledit dispositif de traitement (14) est configuré pour entraîner lesdits transducteurs à ultrasons focalisés (18) pour commencer à recevoir ledit quatrième signal d’ultrasons (U4) uniquement durant ladite période prédéfinie après ladite période d’estimation,
dans lequel ledit dispositif de traitement (14) est configuré pour utiliser ledit affichage (16) pour afficher une

seconde image de ladite position cible selon ledit quatrième signal d'ultrasons (U4), dans lequel la luminosité de ladite seconde image est directement proportionnelle à l'intensité d'énergie dudit troisième signal d'ultrasons (U3).

2. Dispositif d'affichage pour une énergie ultrasonore selon la revendication 1, dans lequel lesdits transducteurs à ultrasons focalisés (18) sont agencés en un réseau à deux dimensions ou un réseau en cercle concentrique.

3. Dispositif d'affichage pour une énergie ultrasonore selon la revendication 1, dans lequel ladite première image est affichée selon des premières données filtrées de forme de faisceau *rf*(x_g, z_g), et lesdites premières données filtrées de forme de faisceau *rf*(x_g, z_g) satisfont aux formules suivantes:

$$\tilde{rf}(x_g, z_g) = F \times \sum_{n=1}^{N} \left(\sum_{n=1}^{N} \left(\left(\hat{RF}_{M\times N} \right)^T \times x_{M\times 1} \times \overline{TD_{1\times N}} \right) \right) \;;$$

$$\begin{aligned} RF_{M\times N} \cong{} & \cos(2\pi f_r t) \times (chRF_{M\times N} + chRF_{M\times N}^{*})/2 \\ & - \sin(2\pi f_r t) \times (-j) \times (chRF_{M\times N} + chRF_{M\times N}^{*})/2 \end{aligned}$$

$$IQ_{m\times N} \cong [f_1(k), f_2(k), \ldots, f_i(k), \ldots, f_N(k)] \;;$$

$$\begin{aligned} \hat{chRF}_{M\times N} \cong{} & [f_1(\frac{k}{f_{sIQ}} * f_{sRF}), f_2(\frac{k}{f_{sIQ}} * f_{sRF}), \ldots \\ & , f_i(\frac{k}{f_{sIQ}} * f_{sRF}), \ldots, f_N(\frac{k}{f_{sIQ}} * f_{sRF})] \end{aligned} \;;$$

et

$$T_{M\times N} = x_{M\times 1} \times TD_{1\times N} \,,$$

dans lequel (x_g, z_g) est une coordonnée 3D de ladite position cible, et *F* est un premier facteur filtré, et *N* est le nombre desdits transducteurs à ultrasons focalisés (18), et *n* est un indice de chacun desdits transducteurs à ultrasons focalisés (18), $\hat{RF}_{M\times N}$ et est une première matrice de données de forme de faisceau avec une dimension $M \times N$, et *t* est le temps, et f_r est une première fréquence de re-modulation, et $\hat{chRF}_{M\times N}$ est une première matrice de données de canal avec une dimension $M \times$ N, et $\hat{IQ}_{m\times N}$ est une matrice avec une dimension m x N d'un signal en bande de base dudit deuxième signal d'ultrasons, et m est un nombre naturel, et $f_i(k)$ est une fonction de colonne d'une i^{e} colonne de $\hat{IQ}_{m\times N}$, et k et i sont des nombres naturels, et k = 1, 2, ..., m, et i = 1, 2, ..., N, et f_{sIQ} est une fréquence d'échantillonnage de $\hat{IQ}_{m\times N}$, et f_{sRF} est une fréquence rééchantillonnée de $\hat{IQ}_{m\times N}$, et $\overline{TD_{1\times N}}$ est une première matrice de temps dudit deuxième signal d'ultrasons se déplaçant depuis ladite position cible vers *N* pièces desdits transducteurs à ultrasons focalisés (18), et $T_{M\times N}$ est une matrice avec une dimension *M* x *N* comprenant des éléments 0 et 1, et *M* est un nombre naturel supérieur à un élément le plus large de ladite première matrice de temps, et $x_{M\times 1}$ est un vecteur avec une dimension *M* x 1, et $\hat{chRF}_{M\times N}^{*}$ est une conjugaison de

$\hat{chRF}_{M\times N}$, et ladite période d'estimation égale une distance entre ladite position cible et le transducteur à ultrasons focalisés (18) le plus distal de ladite position cible multipliée par 2 et divisée par ladite vitesse du son.

4. Dispositif d'affichage pour une énergie ultrasonore selon la revendication 1, dans lequel ladite seconde image est affichée selon des secondes données filtrées de forme de faisceau $\tilde{rf}(x_g, z_g)'$, et lesdites secondes données filtrées de forme de faisceau $\tilde{rf}(x_g, z_g)'$ satisfont aux formules suivantes:

$$\tilde{rf}(x_g, z_g)' = F'\times\sum_{n=1}^{N}\left(\sum_{n=1}^{N}\left((\hat{RF'}_{M'\times N})^T \times x'_{M'\times 1}\times\overline{TD'}_{1\times N}\right)\right) \ ;$$

$$\begin{aligned}\hat{RF'}_{M'\times N} &\cong \cos(2\pi f_r' t)\times(\hat{chRF'}_{M'\times N} + \hat{chRF'}_{M'\times N}{}^{*})/2 \\ &\quad - \sin(2\pi f_r' t)\times(-j)\times(\hat{chRF'}_{M'\times N} + \hat{chRF'}_{M'\times N}{}^{*})/2\end{aligned} \ ;$$

$$\hat{IQ'}_{m\times N} \cong [f_1'(k), f_2'(k), \dots, f_i'(k), \dots, f_N'(k)] \ ;$$

$$\begin{aligned}\hat{chRF'}_{M'\times N} \cong [&f_1'(\frac{k}{f_{sIQ}'} * f_{sRF}'), f_2'(\frac{k}{f_{sIQ}'} * f_{sRF}'), \dots \\ &, f_i'(\frac{k}{f_{sIQ}'} * f_{sRF}'), \dots, f_N'(\frac{k}{f_{sIQ}'} * f_{sRF}')]\end{aligned} \ ;$$

et

$$T'_{M'\times N} = x'_{M'\times 1}\times\overline{TD'}_{1\times N} \ ,$$

dans lequel (x_g, z_g) est une coordonnée 3D de ladite position cible, et *F'* est un second facteur filtré, et *N* est le nombre desdits transducteurs à ultrasons focalisés (18), et *n* est un indice de chacun desdits transducteurs à ultrasons focalisés (18), et $\hat{RF'}_{M'\times N}$ est une seconde matrice de données de forme de faisceau avec une dimension *M'* x *N*, et *t* est le temps, et f_r' est une seconde fréquence de re-modulation, et $\hat{chRF'}_{M'\times N}$ est une seconde matrice de données de canal avec une dimension *M'* x *N*, et $\hat{IQ'}_{m\times N}$ est une matrice avec une dimension *m* x *N* d'un signal en bande de base dudit quatrième signal d'ultrasons, et m est un nombre naturel, et $f_i'(k)$ est une fonction de colonne d'une i^e colonne de $\hat{IQ'}_{m\times N}$, et k et i sont des nombres naturels, et k = 1, 2, ..., m, et i = 1, 2, ..., N, et f_{sIQ}' est une fréquence d'échantillonnage de $\hat{IQ'}_{m\times N}$, et f_{sRF}' est une fréquence rééchantillonnée de $\hat{IQ'}_{m\times N}$, et $\overline{TD'}_{1\times N}$ est une seconde matrice de temps dudit quatrième signal d'ultrasons se déplaçant depuis ladite position cible vers N pièces desdits transducteurs à ultrasons focalisés (18), et $T_{M\times N}$ est une matrice avec une dimension *M'* x *N* comprenant des éléments 0 et 1, et *M'* est un nombre naturel supérieur à un élément le plus large de ladite seconde matrice de temps, et $x'_{M' \times 1}$ est un vecteur avec une dimension $M' \times 1$, et $chRF'^{*}_{M' \times N}$ est une conjugaison de $ch\ddot{R}F'_{M' \times N}$, et ladite période d'estimation égale une distance entre ladite position cible et le transducteur à ultrasons focalisés (18) le plus distal de ladite position cible multipliée par 2 et divisée par ladite vitesse du son.

5. Dispositif d'affichage pour une énergie ultrasonore comprenant:

un dispositif d'émission et de réception d'ultrasons focalisés (10) pour émettre au moins un premier signal d'ultrasons (U1) à une position cible d'un organisme (17), dans lequel ladite position cible reflète ledit premier signal d'ultrasons (U1) pour former au moins un deuxième signal d'ultrasons (U2);
un dispositif de traitement (14) raccordé avec ledit dispositif d'émission et de réception d'ultrasons focalisés (10) pour définir une période d'estimation selon une distance entre ledit dispositif d'émission et de réception d'ultrasons focalisés (10) et ladite position cible et la vitesse du son, dans lequel ledit dispositif de traitement (14) est configuré pour générer un premier signal électrique (E1) et transmettre ledit premier signal électrique (E1) audit dispositif d'émission et de réception d'ultrasons focalisés (10) pour commander ledit dispositif d'émission et de réception d'ultrasons focalisés (10) pour émettre ledit premier signal d'ultrasons (U1), dans lequel ensuite ledit dispositif de traitement (14) est configuré pour entraîner ledit dispositif d'émission et de réception d'ultrasons focalisés (10) pour commencer à recevoir ledit deuxième signal d'ultrasons (U2) uniquement durant une période prédéfinie après ladite période d'estimation, dans lequel ladite période prédéfinie est égale ou supérieure à un temps de réponse dudit dispositif d'émission et de réception d'ultrasons focalisés (10);
dans lequel ledit dispositif d'émission et de réception d'ultrasons focalisés (10) comprend en outre au moins un émetteur d'ultrasons focalisés (20) et au moins un récepteur d'ultrasons focalisés (22) raccordés avec ledit dispositif de traitement (14),
dans lequel ledit émetteur d'ultrasons focalisés (20) est entouré par ledit récepteur d'ultrasons focalisés (22),
dans lequel ledit émetteur d'ultrasons focalisés (20) est configuré pour recevoir ledit premier signal électrique (E1) et générer ledit premier signal d'ultrasons (U1) selon ledit premier signal électrique (E1),
dans lequel ledit dispositif de traitement (14) est configuré pour entraîner ledit récepteur d'ultrasons focalisés (22) pour recevoir ledit deuxième signal d'ultrasons (U2),
dans lequel ladite période prédéfinie est égale ou supérieure à un temps de réponse dudit récepteur d'ultrasons focalisés (22),
dans lequel un affichage (16) est raccordé avec ledit dispositif de traitement (14), **caractérisé en ce que** ledit dispositif de traitement (14) est configuré pour utiliser ledit affichage (16) pour afficher une première image de ladite position cible selon ledit deuxième signal d'ultrasons (U2),
dans lequel une luminosité de ladite première image est directement proportionnelle à l'intensité d'énergie dudit premier signal d'ultrasons (U2),
dans lequel ledit dispositif de traitement (14) est configuré pour convertir ledit premier signal électrique (E1) en un second signal électrique (E2) selon une différence entre ladite luminosité de ladite première image et une luminosité prédéfinie,
dans lequel ledit récepteur d'ultrasons focalisés (22) est configuré pour recevoir ledit second signal électrique (E2), dans lequel ledit émetteur d'ultrasons focalisés (20) est configuré pour utiliser ledit second signal électrique (E2) pour émettre au moins un troisième signal d'ultrasons (U3) dont l'intensité d'énergie est supérieure à l'intensité d'énergie dudit premier signal d'ultrasons (U1) à ladite position cible qui reflète ledit troisième signal d'ultrasons (U3) pour former au moins un quatrième signal d'ultrasons (U4),
dans lequel, après avoir généré ledit troisième signal d'ultrasons (U3), ledit dispositif de traitement (14) est configuré pour entraîner ledit récepteur d'ultrasons focalisés (22) pour commencer à recevoir ledit quatrième signal d'ultrasons (U4) uniquement durant ladite période prédéfinie après ladite période d'estimation, dans lequel ledit dispositif de traitement (14) est configuré pour utiliser ledit affichage (16) pour afficher une seconde image de ladite position cible selon ledit quatrième signal d'ultrasons (U4),
dans lequel la luminosité de ladite seconde image est directement proportionnelle à l'intensité d'énergie dudit troisième signal d'ultrasons (U3).

6. Dispositif d'affichage pour une énergie ultrasonore selon la revendication 5, dans lequel ledit au moins un émetteur d'ultrasons focalisés (20) est une pluralité d'émetteurs d'ultrasons focalisés (20) agencés en un réseau de bandes avec une dimension, et le nombre dudit récepteur d'ultrasons focalisés (22) est un, et lesdits émetteurs d'ultrasons focalisés (20) et ledit récepteur d'ultrasons focalisés (22) sont agencés sur une surface incurvée.

7. Dispositif d'affichage pour une énergie ultrasonore selon la revendication 5, dans lequel ledit au moins un récepteur d'ultrasons focalisés (22) est une pluralité de récepteurs d'ultrasons focalisés (22) agencées en un réseau en anneau, et le nombre dudit émetteur d'ultrasons focalisés (20) est un, et lesdits récepteurs d'ultrasons focalisés (22) et ledit émetteur d'ultrasons focalisés (20) sont agencés sur une surface incurvée.

8. Dispositif d'affichage pour une énergie ultrasonore selon la revendication 5, dans lequel ladite première image est affichée selon des premières données filtrées de forme de faisceau $\tilde{rf}(x_g,z_g)$, et lesdites premières données filtrées de forme de faisceau $\tilde{rf}(x_g,z_g)$ satisfont aux formules suivantes

$$\tilde{rf}(x_g,z_g) = F \times \sum\nolimits_{n=1}^{N} \left(\sum\nolimits_{n=1}^{N} \left(\left(\hat{R}F_{M\times N}\right)^T \times x_{M\times 1} \times \overline{TD_{1\times N}}\right)\right) \;;$$

$$\begin{aligned}\hat{R}F_{M\times N} \cong{} & \cos(2\pi f_r t)\times\left(ch\hat{R}F_{M\times N} + ch\hat{R}F_{M\times N}{}^{*}\right)/2 \\ & -\sin(2\pi f_r t)\times(-j)\times\left(ch\hat{R}F_{M\times N} + ch\hat{R}F_{M\times N}{}^{*}\right)/2\end{aligned}$$

$$\hat{I}Q_{m\times N} \cong [f_1(k), f_2(k), \ldots, f_i(k), \ldots, f_N(k)] \;;$$

$$\begin{aligned}ch\hat{R}F_{M\times N} \cong{} & [f_1(\frac{k}{f_{sIQ}} * f_{sRF}), f_2(\frac{k}{f_{sIQ}} * f_{sRF}), \ldots \\ & , f_i(\frac{k}{f_{sIQ}} * f_{sRF}), \ldots, f_N(\frac{k}{f_{sIQ}} * f_{sRF})]\end{aligned} \;;$$

et

$$T_{M\times N} = x_{M\times 1} \times \overline{TD_{1\times N}} \,,$$

dans lequel (x_g, z_g) est une coordonnée 3D de ladite position cible, et F est un premier facteur filtré, et N est le nombre dudit récepteur d'ultrasons focalisés, et n est un indice de chacun dudit récepteur d'ultrasons focalisés, et $\hat{R}F_{M\times N}$ est une première matrice de données de forme de faisceau avec une dimension M x N, et t est le temps, et f_r est une première fréquence de re-modulation, et $ch\hat{R}F_{M\times N}$ est une première matrice de données de canal avec une dimension M x N, et $\hat{I}Q_{m\times N}$ est une matrice avec une dimension m x N d'un signal en bande de base dudit deuxième signal d'ultrasons, et m est un nombre naturel, et $f_i(k)$ est une fonction de colonne d'une i^e colonne de $\hat{I}Q_{m\times N}$, et k et i sont des nombres naturels, et k = 1, 2, ..., m, et i = 1, 2, ..., N, et f_{sIQ} est une fréquence d'échantillonnage de $\hat{I}Q_{m\times N}$, et f_{sRF} est une fréquence rééchantillonnée de $\hat{I}Q_{m\times N}$ et $\overline{TD_{1\times N}}$ est une première matrice de temps dudit deuxième signal d'ultrasons se déplaçant depuis ladite position cible vers N pièces desdits récepteurs d'ultrasons focalisés, et $T_{M \times N}$ est une matrice exploitée par masquage avec une dimension M x N comprenant des éléments 0 et 1, et M est un nombre naturel supérieur à un élément le plus large de ladite première matrice de temps, et $x_{M \times 1}$ est un vecteur avec une dimension M x 1, et $ch\hat{R}F_{M\times N}{}^*$ est une conjugaison de $ch\hat{R}F_{M\times N}$ et ladite période d'estimation égale une distance entre ladite position cible et ledit récepteur d'ultrasons focalisés (22) le plus distal de ladite position cible multipliée par 2 et divisée par ladite vitesse du son.

9. Dispositif d'affichage pour une énergie ultrasonore selon la revendication 5, dans lequel ladite seconde image est affichée selon des secondes données filtrées de forme de faisceau $\tilde{rf}(x_g,z_g)$', et lesdites secondes données filtrées de forme de faisceau $\tilde{rf}(x_g,z_g)$' satisfont aux formules suivantes :

$$\tilde{rf}(x_g, z_g)' = F' \times \sum_{n=1}^{N} \left(\sum_{n=1}^{N} \left((\hat{RF}'_{M' \times N})^T \times x'_{M' \times 1} \times \overline{TD'_{1 \times N}} \right) \right) \ ;$$

$$\hat{RF}'_{M' \times N} \cong \cos(2\pi f_r' t) \times (\hat{chRF}'_{M' \times N} + \hat{chRF}'^{\,*}_{M' \times N}) / 2$$

$$- \sin(2\pi f_r' t) \times (-j) \times (\hat{chRF}'_{M' \times N} + \hat{chRF}'^{\,*}_{M' \times N}) / 2$$

$$\hat{IQ}'_{m' \times N} \cong [f_1'(k), f_2'(k), \ldots, f_i'(k), \ldots, f_N'(k)] \ ;$$

$$\hat{chRF}'_{M' \times N} \cong [f_1'(\frac{k}{f_{sIQ}'} * f_{sRF}'), f_2'(\frac{k}{f_{sIQ}'} * f_{sRF}'), \ldots, f_i'(\frac{k}{f_{sIQ}'} * f_{sRF}'), \ldots, f_N'(\frac{k}{f_{sIQ}'} * f_{sRF}')] \ ;$$

et

$$T'_{M' \times N} = x'_{M' \times 1} \times \overline{TD'_{1 \times N}} \ ,$$

dans lequel (x_g, z_g) est une coordonnée 3D de ladite position cible, et *F'* est un second facteur filtré, et *N* est le nombre dudit récepteur d'ultrasons focalisés, et *n* est un indice de chacun dudit récepteur d'ultrasons focalisés, et $\hat{RF}'_{M' \times N}$ est une seconde matrice de données de forme de faisceau avec une dimension *M'* x *N*, et *t* est le temps, et f_r' est une seconde fréquence de re-modulation, et $\hat{chRF}'_{M \times N}$ est une seconde matrice de données de canal avec une dimension *M'* x *N*, et $\hat{IQ}'_{m \times N}$ est une matrice avec une dimension *m* x *N* d'un signal en bande de base dudit quatrième signal d'ultrasons, et m est un nombre naturel, et $f_i'(k)$ est une fonction de colonne d'une i^e colonne de $\hat{IQ}'_{m \times N}$, et k et i sont des nombres naturels, et k = 1, 2, ..., m, et i = 1, 2, ..., N, et f_{sIQ}' est une fréquence d'échantillonnage de $\hat{IQ}'_{m \times N}$, et f_{sRF}' est une fréquence rééchantillonnée de $\hat{IQ}'_{m \times N}$, et $\overline{TD'_{1 \times N}}$ est une seconde matrice de temps dudit quatrième signal d'ultrasons se déplaçant depuis ladite position cible vers *N* pièces desdits récepteurs d'ultrasons focalisés, et $T'_{M \times N}$ est une matrice avec une dimension *M'* x *N* comprenant des éléments 0 et 1, et *M'* est un nombre naturel supérieur à un élément le plus large de ladite seconde matrice de temps, et $x'_{M' \times 1}$ est un vecteur avec une dimension *M'* x 1, et $\hat{chRF}'^{\,*}_{M \times N}$ est une conjugaison de $chRF'_{M' \times N}$, et ladite période d'estimation égale une distance entre ladite position cible et ledit récepteur d'ultrasons focalisés (22) le plus distal de ladite position cible multipliée par 2 et divisée par ladite vitesse du son.

10. Dispositif d'affichage pour une énergie ultrasonore selon les revendications 1 ou 5, dans lequel ledit troisième signal d'ultrasons (U3) et ledit quatrième signal d'ultrasons (U4) sont des ondes en rafale.

11. Dispositif d'affichage pour une énergie ultrasonore selon la revendication 10, dans lequel ledit premier signal d'ultrasons (U1) et ledit deuxième signal d'ultrasons (U2) sont des ondes en rafale.

12. Dispositif d'affichage pour une énergie ultrasonore selon la revendication 10, dans lequel ledit premier signal d'ultrasons (U1) et ledit troisième signal d'ultrasons (U3) sont configurés pour pénétrer à travers l'os crânien pour atteindre ladite position cible, et la fréquence dudit premier signal d'ultrasons (U1) et dudit troisième signal d'ultrasons (U3) est inversement proportionnelle à l'épaisseur dudit os crânien.

13. Dispositif d'affichage pour une énergie ultrasonore selon les revendications 1 ou 5 configuré pour ledit organisme (17) étant un tissu du système nerveux central (CNS) présentant des capillaires contenant la barrière hémato-encéphalique.

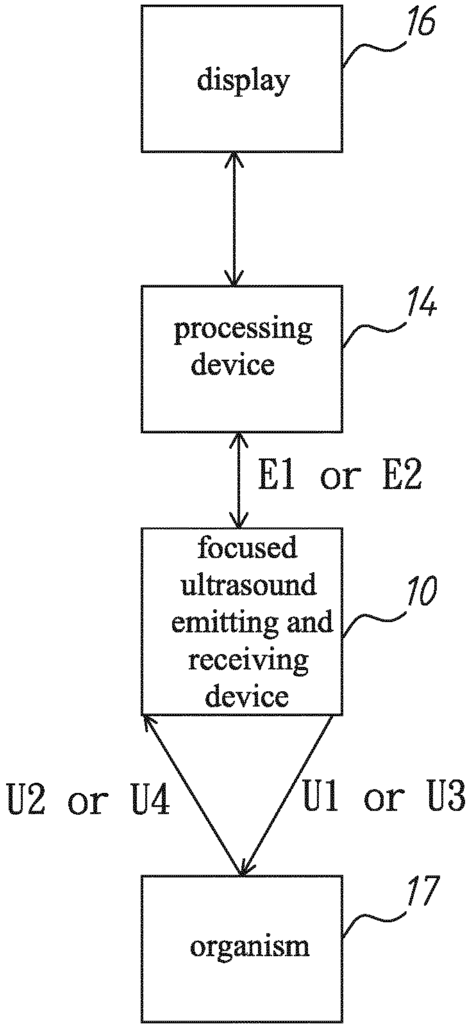

display
16
processing device
14
E1 or E2
focused ultrasound emitting and receiving device
10
U2 or U4
U1 or U3
organism
17

Fig. 1

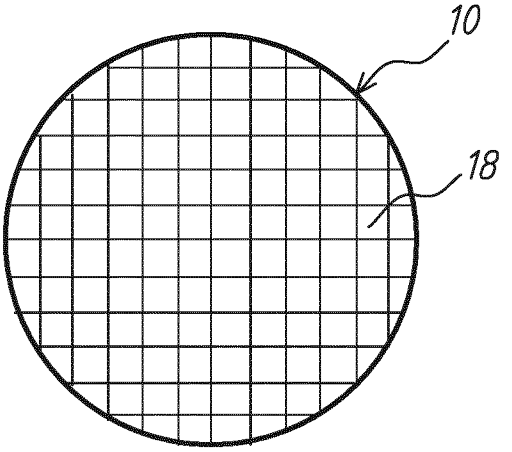


Fig. 2

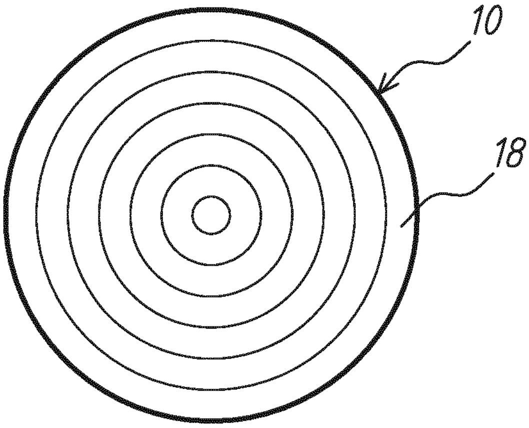
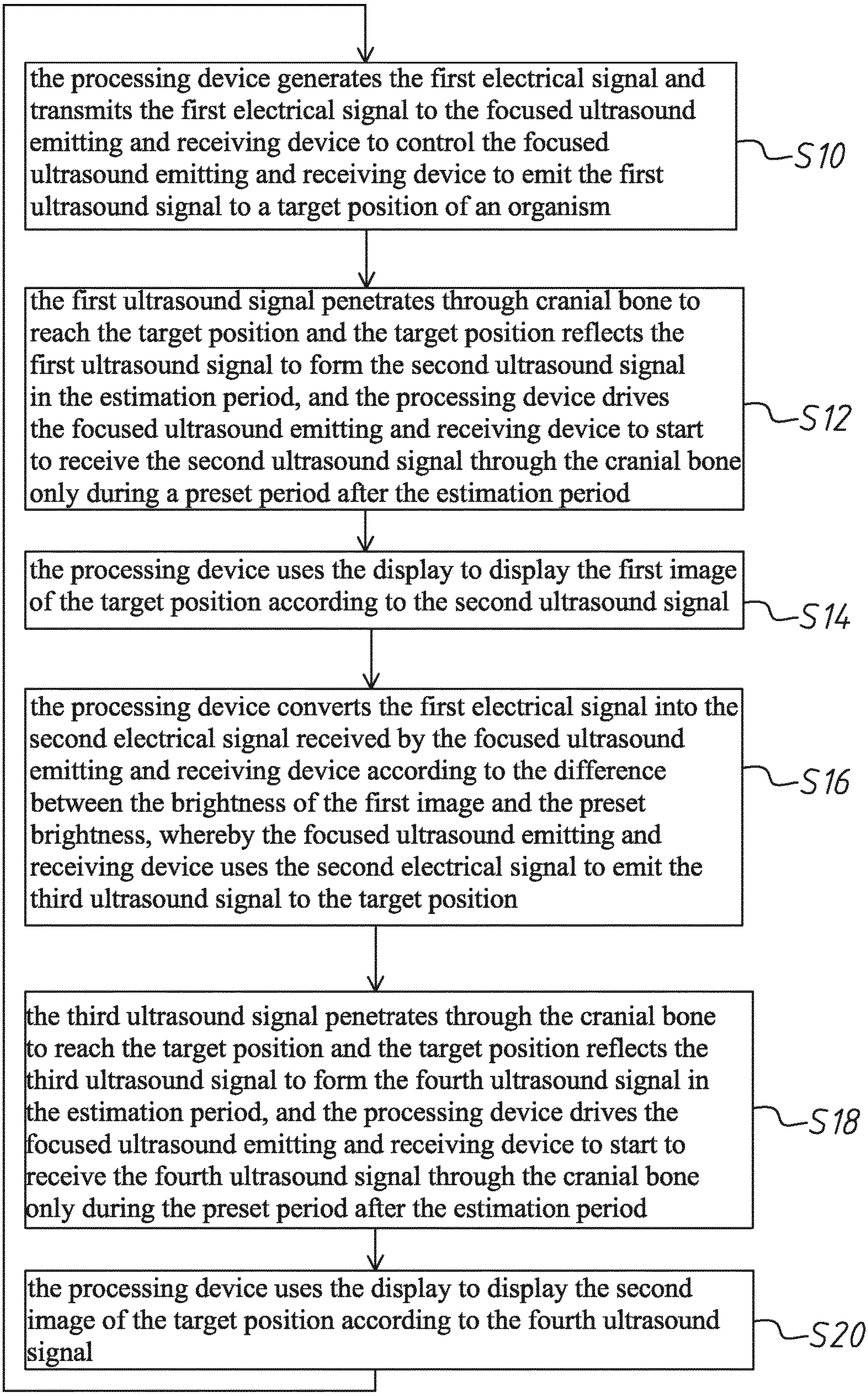


Fig. 3


the processing device generates the first electrical signal and transmits the first electrical signal to the focused ultrasound emitting and receiving device to control the focused ultrasound emitting and receiving device to emit the first ultrasound signal to a target position of an organism

the first ultrasound signal penetrates through cranial bone to reach the target position and the target position reflects the first ultrasound signal to form the second ultrasound signal in the estimation period, and the processing device drives the focused ultrasound emitting and receiving device to start to receive the second ultrasound signal through the cranial bone only during a preset period after the estimation period

the processing device uses the display to display the first image of the target position according to the second ultrasound signal

the processing device converts the first electrical signal into the second electrical signal received by the focused ultrasound emitting and receiving device according to the difference between the brightness of the first image and the preset brightness, whereby the focused ultrasound emitting and receiving device uses the second electrical signal to emit the third ultrasound signal to the target position

the third ultrasound signal penetrates through the cranial bone to reach the target position and the target position reflects the third ultrasound signal to form the fourth ultrasound signal in the estimation period, and the processing device drives the focused ultrasound emitting and receiving device to start to receive the fourth ultrasound signal through the cranial bone only during the preset period after the estimation period

the processing device uses the display to display the second image of the target position according to the fourth ultrasound signal

Fig. 4

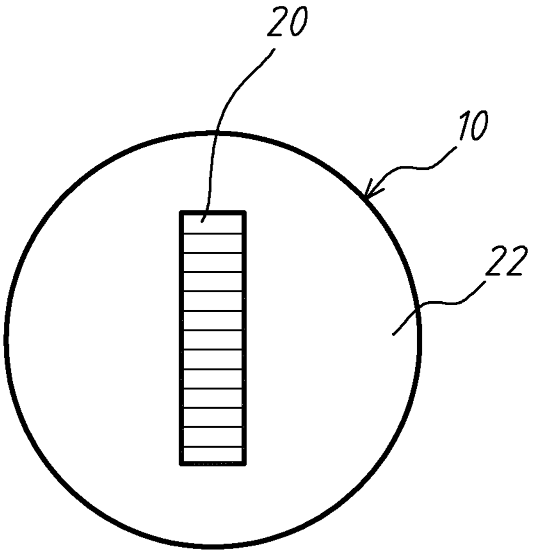


Fig. 5

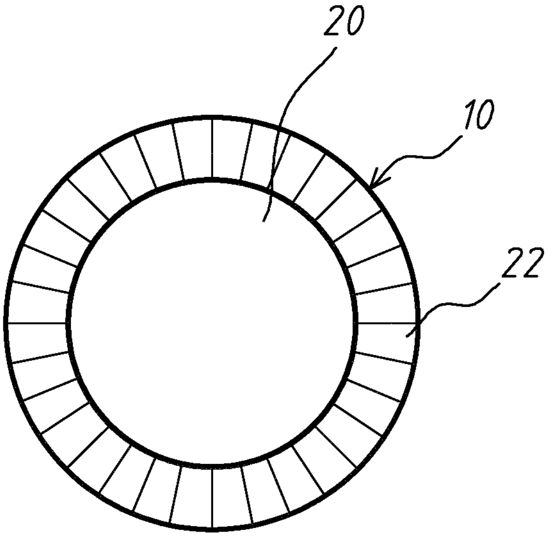


Fig. 6

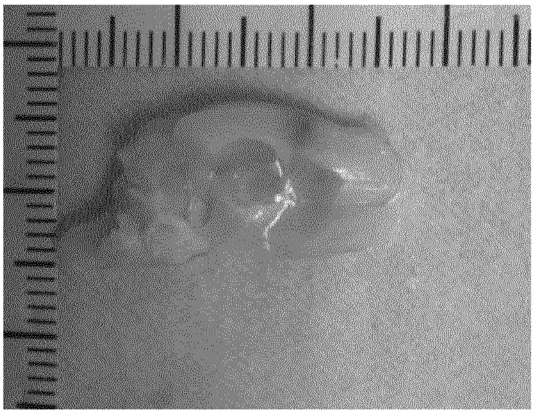


Fig.7(a)

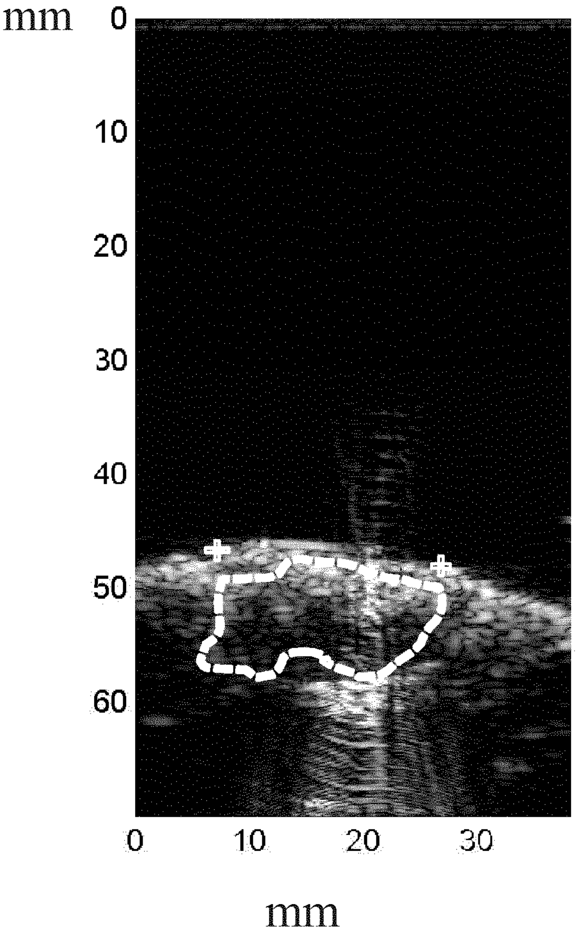


Fig.7(b)

Fig.8(a)

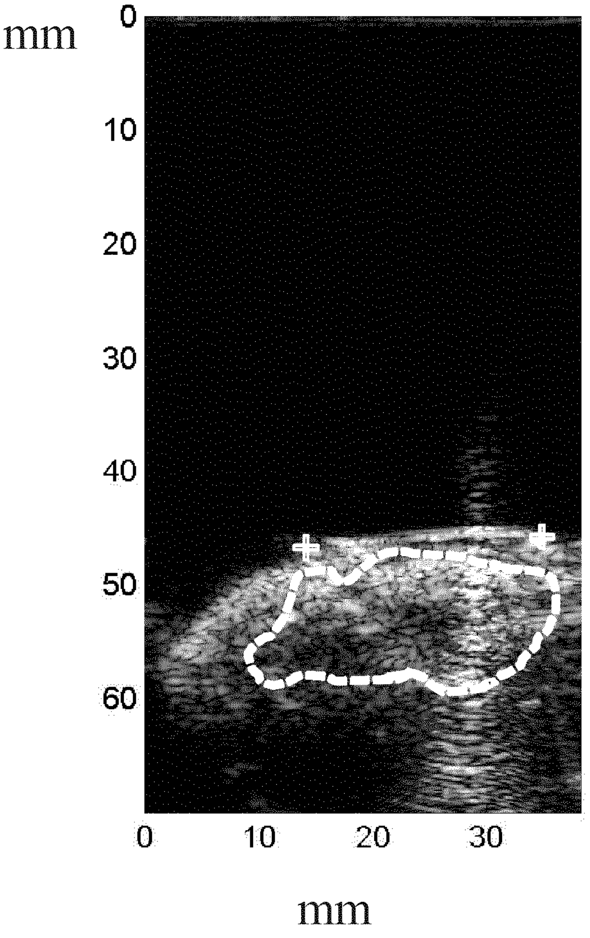


Fig.8(b)

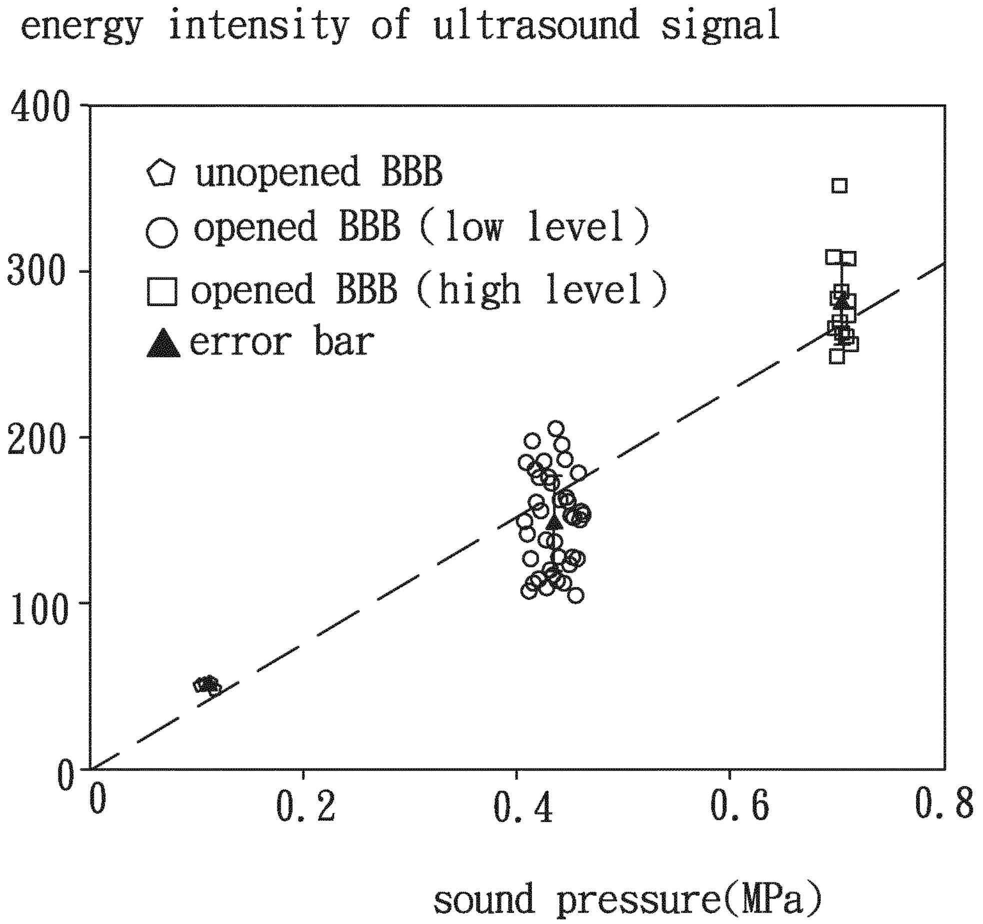

energy intensity of ultrasound signal
400
300
200
100
0
⬠ unopened BBB
○ opened BBB (low level)
□ opened BBB (high level)
▲ error bar
0
0.2
0.4
0.6
0.8
sound pressure(MPa)

Fig. 9

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- US 6508774 B1 **[0004]**
- US 20150182195 A1 **[0004]**

专利名称(译)	超声波能量显示装置		
公开(公告)号	EP3326538B1	公开(公告)日	2020-05-06
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申请(专利权)人(译)	长庚大学		
当前申请(专利权)人(译)	长庚大学		
[标]发明人	LIU HAO LI		
发明人	LIU, HAO-LI XIA, JING-JING		
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摘要(译)

用于超声能量的显示设备包括聚焦超声发射和接收设备，处理设备和显示器。 处理设备生成第一电信号并将其传输到聚焦超声发射和接收设备，以控制聚焦超声发射和接收设备将至少一个第一超声信号发射到生物体的目标位置。 目标位置反射第一超声信号以形成至少一个第二超声信号。 在产生第一电信号之后，处理设备驱动聚焦超声发射和接收设备仅在估计周期之后的预设周期内开始接收第二超声信号。 所述处理装置利用所述显示器根据所述第二超声信号显示所述目标位置的图像，所述图像的亮度与所述第一超声信号的能量强度成正比。

$$\tilde{rf}(x_g, z_g),$$