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(54) METHOD FOR EXPLORING AND DISPLAYING TISSUES FO HUMAN OR ANIMAL ORIGIN FROM A HIGH FREQUENCY ULTRASOUND PROBE

(75) Inventors: **Amena Saied**, Paris (FR); **Genevieve Berger**, Bourg-La-Reine (FR); **Pascal Laugier**, Paris (FR); **Michel Puech**, Paris (FR)

Correspondence Address:
CONNOLLY BOVE LODGE & HUTZ LLP
SUITE 800
1990 M STREET NW
WASHINGTON, DC 20036-3425 (US)

(73) Assignee: **Centre National de la Recherche Scientifique**, Paris (FR)

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(30) **Foreign Application Priority Data**

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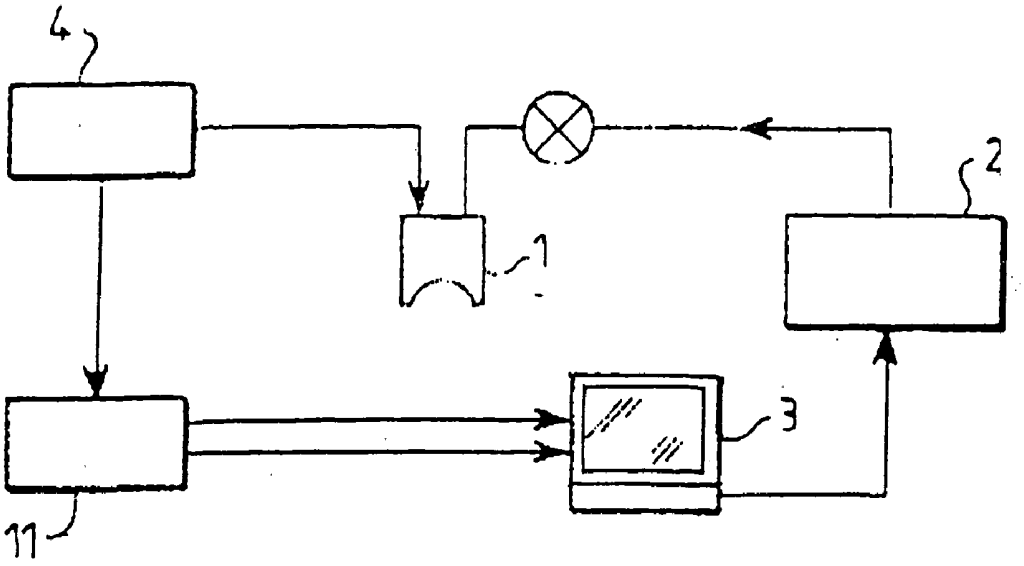
(57) **ABSTRACT**

A method for displaying scanned ultrasound images of tissue employs an apparatus including an ultrasound probe mounted to a mechanical head. A three-dimensional positioning system mounts the head for positioning the probe in proximate orthogonal relation to the tissue. A computer controls the three-dimensional positioning system thereby moving the probe during a scan. The probe transmits high frequency ultrasound waves whose nominal frequency is included within the range from 30 to 100 MHz and with a large pass band, adapted to frequencies reflected by the tissue. The beams of ultrasound transmission are focused in a given zone of the tissue over a vertical penetration distance of between 20 and 30 mm. Reflected signals are acquired and processed for display.



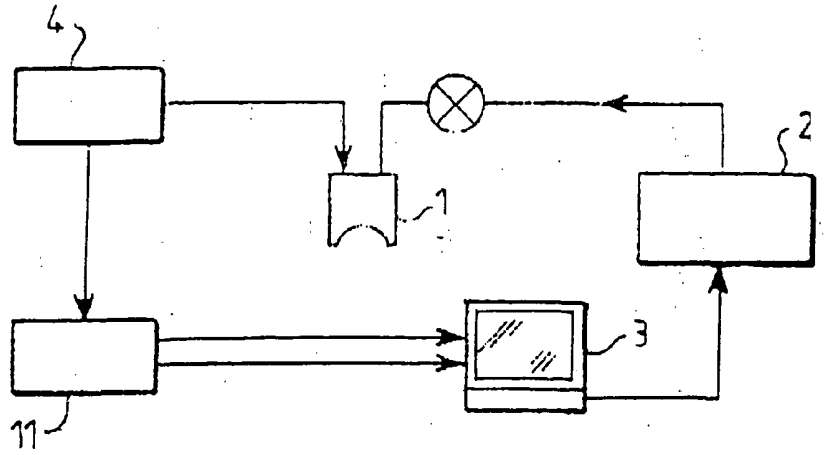


FIG. 1

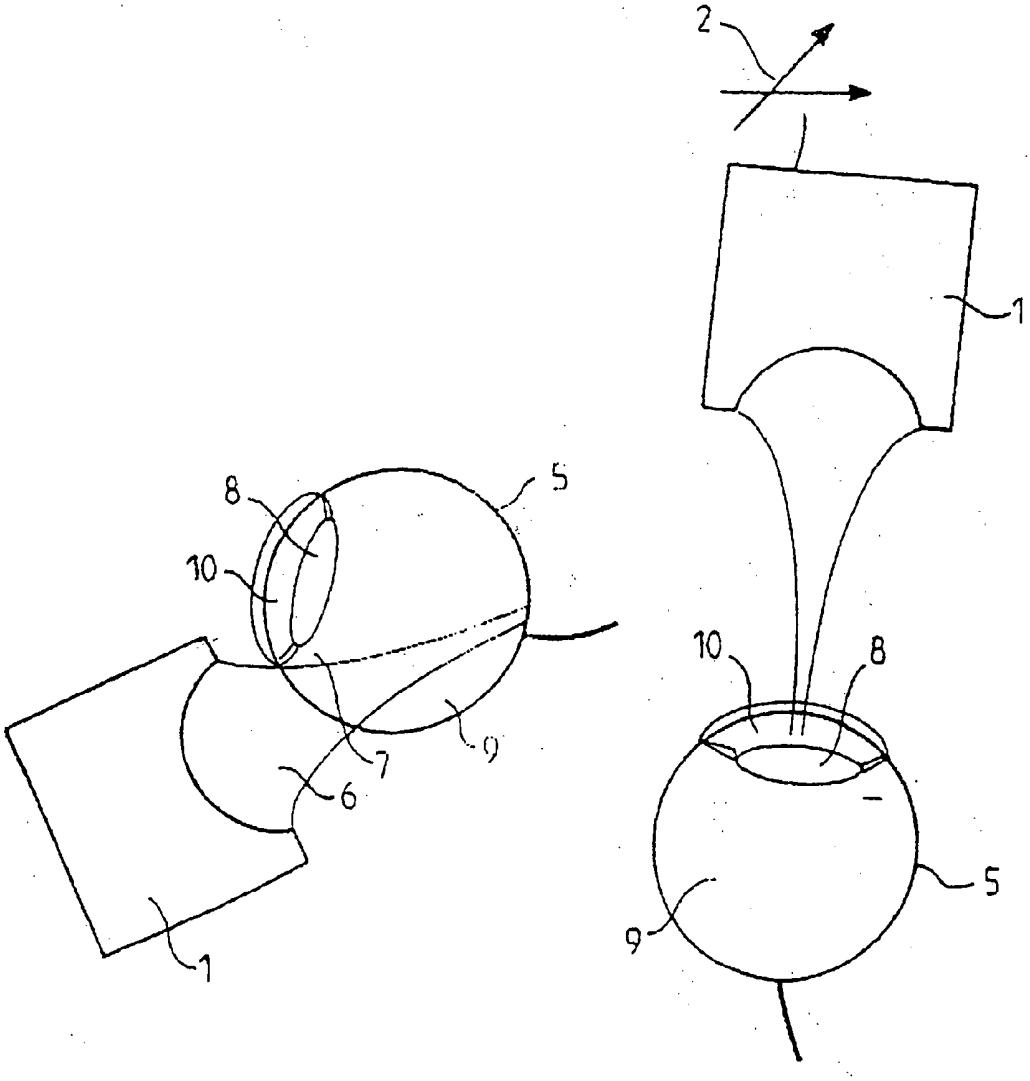


FIG. 2

FIG. 3

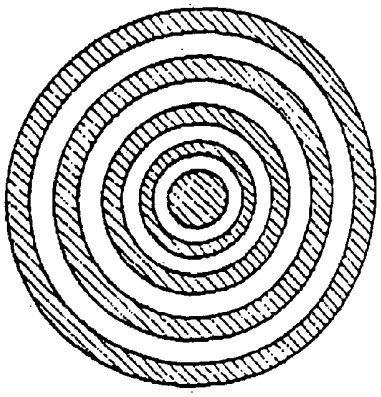


FIG.4a

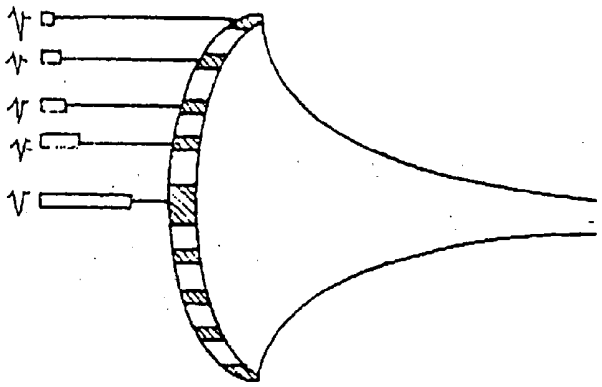


FIG.4b

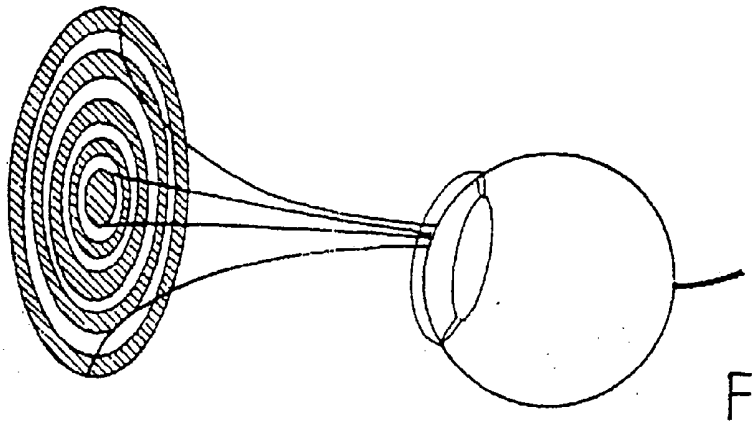


FIG.5

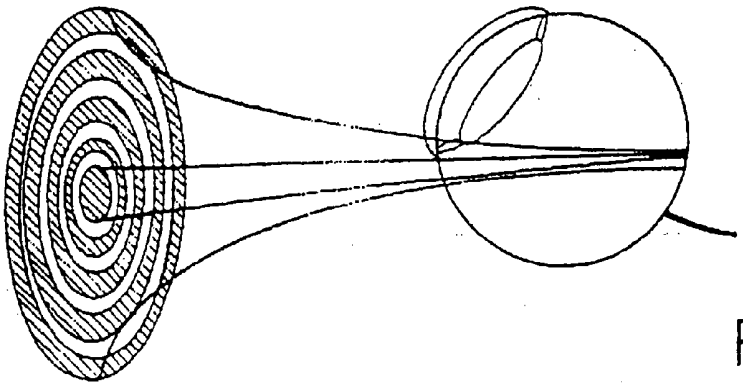


FIG.6

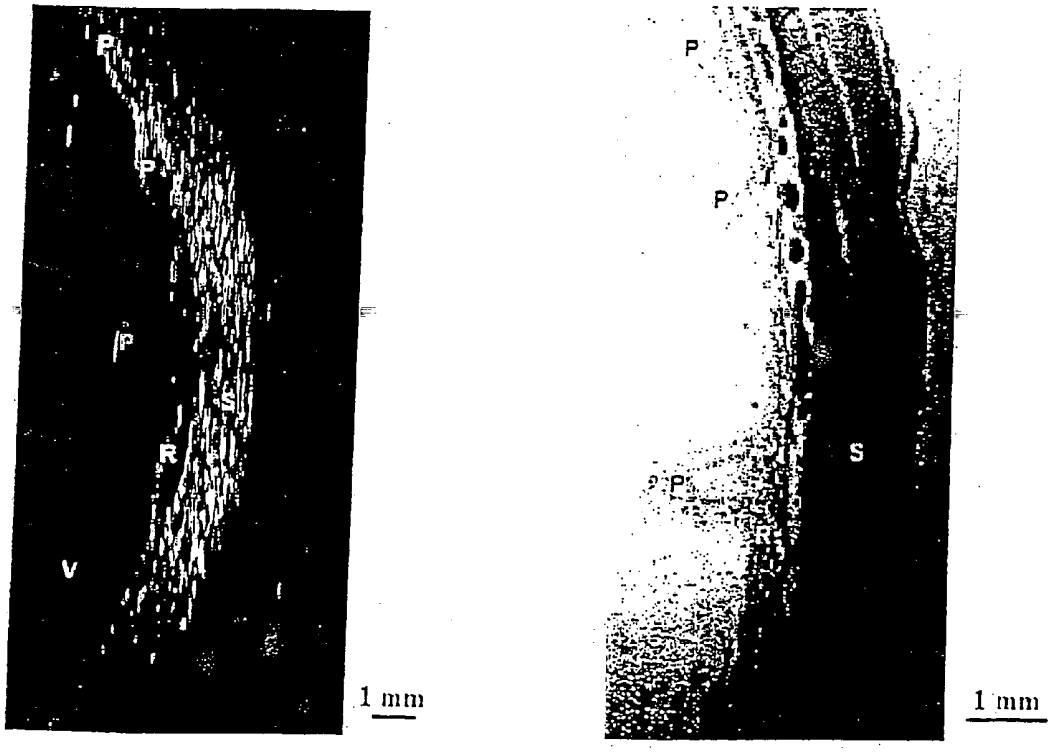


Figure 7

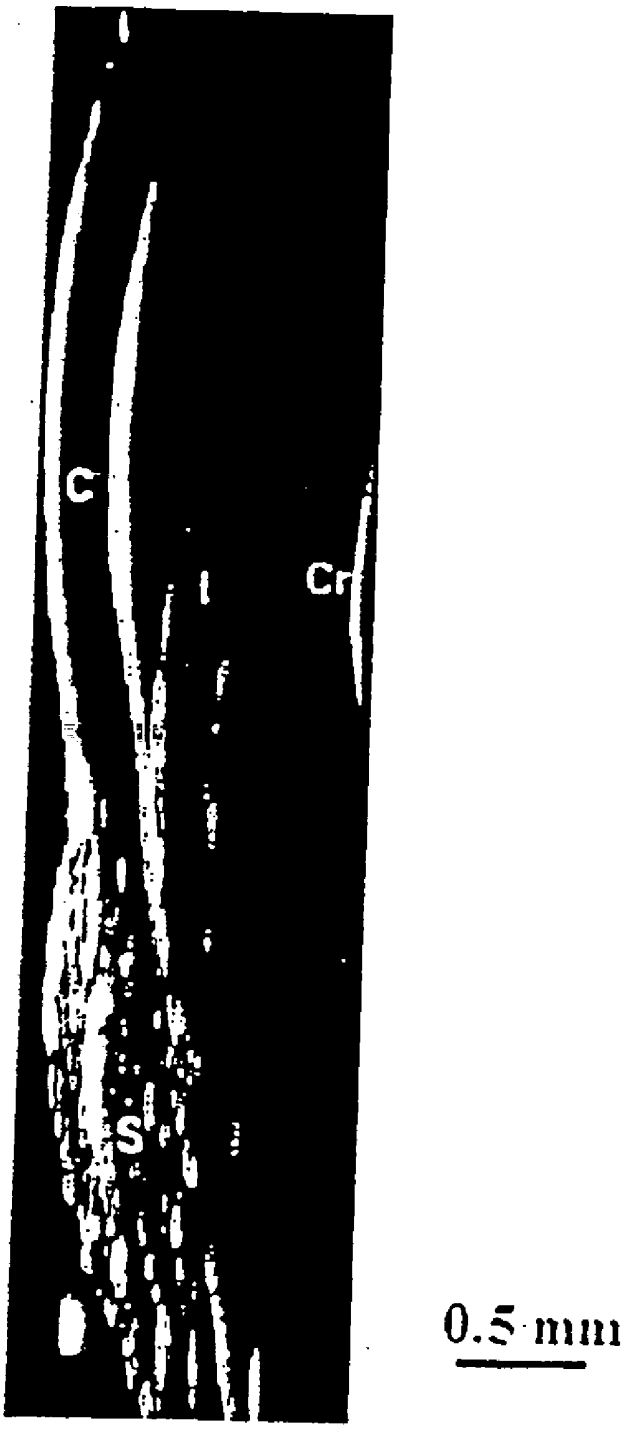


Figure 8

METHOD FOR EXPLORING AND DISPLAYING TISSUES FO HUMAN OR ANIMAL ORIGIN FROM A HIGH FREQUENCY ULTRASOUND PROBE

CROSS REFERENCE INFORMATION

[0001] This application is a Continuation of co-pending Application Ser. No. 09/600,073, filed on Feb. 5, 2001, which is the national phase of PCT International Application No. PCT/FR99/00040 filed on Jan. 12, 1999, which designated the United States, and on which priority is claimed under 35 U.S.C. § 120; and this application claims priority of Application No. 98-00209 filed in France on Jan. 12, 1998 under 35 U.S.C. § 119. The entire contents of all are hereby incorporated by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to a process for the investigation and display, using ultrasound echography techniques, of tissue structures of human or animal origin such as in particular the ocular globes and more particularly of the posterior segment (the vitreous cavity, the posterior wall of the globe lined by the choroid and the retina, the macula), tissue structures of the anterior segment (the cornea, the anterior chamber, the iris and the crystalline lens). The invention also relates to a device and an ultrasound probe which allow this investigation and this display to be achieved in 2D or 3D.

BACKGROUND OF THE INVENTION

[0003] In ultrasound imaging and more particularly in medical echography, the choice of frequency is dictated by the compromise between resolution and penetration depth. Specifically, because of the increase in attenuation of ultrasound waves with frequency, the penetration depth of ultrasound increases with decreasing frequency. However, the image resolution decreases with decreasing frequency.

[0004] In addition, a process for the investigation and display of human tissues is known, through document U.S. Pat. No. 5,178,148, for determining the volume of a tumour or of a gland using signals coming from a probe steered by the process.

[0005] Processes are known, in particular through patent FR 2,620,327, for the investigation of ocular structures, by echography, using probes operating at low frequencies of the order of 10 MHz, and focused to a depth roughly equal to the size of an ocular globe (about 23 to 25 mm). These processes mean, on one hand, that images in section of the posterior segment of the eye can be achieved with spatial resolutions of the order of a millimetre and, on the other hand, that a very rough examination of the entire anterior segment of the eye can be carried out.

[0006] The major drawback of low-frequency echography is mainly the low resolution (600 to 700 μm) provided by these low frequencies, which do not allow detailed analysis of the retina and the other layers of the posterior wall of the eye (choroid and sclera) and more particularly in the macular region.

[0007] In order to increase both the lateral and axial resolution, investigation and display processes using ultrasound probes at high frequency, of the order of 50 to 100 MHz (cf. U.S. Pat. No. 5,551,432 and C. J. PAVLIN, M. D. SHERAR, F. S. FOSTER: "Subsurface ultrasound microscopic imaging of the intact eye", Ophthalmology 97: 244, 1990), with a short focal length (of about 4 to 8 mm), have enabled the use, with a resolution of 50 μm, of structures of the anterior segment of the eye, to depths of the order of 5 mm, or of structures of the peripheral retina which are very close to the anterior segment.

[0008] In conclusion, it is therefore accepted that the use of high frequencies seems to be limited to investigation of the anterior segment and the peripheral retina, whereas investigation of the deep structures (posterior segment) requires the use of much lower frequencies, while only providing very low spatial resolutions, of a few hundred microns.

BRIEF DESCRIPTION OF THE INVENTION

[0009] The present invention aims to alleviate the drawbacks of the known processes of the prior art, by proposing an investigation and display process using a high-frequency ultrasound probe which combines both very high spatial resolution and a field of investigation covering the anterior and posterior segments of the ocular globe.

[0010] To this end, the process for the investigation and display of tissues of human or animal origin is characterized in that:

[0011] an ultrasound probe is positioned, said probe being carried by a head steered by means of a three-dimensional positioning system, in particular a system controlled by a computer at right angles to said tissue structure,

[0012] the probe is controlled such that it generates beams of convergent high-frequency ultrasound waves whose nominal frequency is included within the range from 30 to 100 MHz with a broad bandwidth, adapted to the frequencies reflected by the structure investigated, these waves being focused on a given area of tissue structure,

[0013] the tissue structure is scanned by the positioning system steered by the computer, while said computer carries out, in parallel, the acquisition of the signals reflected by the tissue structure,

[0014] various signal processing operations are carried out on the data coming from the scanning, to improve the reproduction of the information and to facilitate the interpretation thereof by the practitioner.

[0015] According to another advantageous characteristic of the invention, the probe is excited such that it generates wave beams whose nominal frequency is included within the range from 30 to 100 MHz with a broad bandwidth, adapted to the frequencies reflected by the structure investigated.

[0016] According to yet another advantageous characteristic of the invention, the wave beams are focused over a vertical penetration distance of between 20 and 30 mm.

[0017] Other characteristics and advantages of the present invention will emerge from the description given hereinbelow, with reference to the appended drawings which illustrate an entirely non-limiting embodiment of the invention. In the figures:

BRIEF DESCRIPTION OF THE FIGURES

[0018] **FIG. 1** is a synoptic view of a device enabling the process forming the subject of the invention to be implemented;

[0019] **FIG. 2** is a view illustrating a use of the process forming the subject of the invention for the investigation of the posterior segment of an ocular globe;

[0020] **FIG. 3** is a view illustrating a use of the process forming the subject of the invention for the investigation of the anterior segment of an ocular globe;

[0021] **FIGS. 4***a* and **4***b* illustrate, on one hand, a front view of one embodiment of the ultrasound probe consisting of an annular array whose focus point can be modified electronically and, on the other hand, a side view of this same probe into which a phase difference has been introduced at transmission or at reception between the various rings making up the array;

[0022] **FIG. 5** is a view illustrating a use of the process forming the subject of the invention for the investigation of the anterior segment of an ocular globe, using a dynamic focusing probe;

[0023] **FIG. 6** is a view illustrating a use of the process forming the subject of the invention for the investigation of the posterior segment of an ocular globe, using a dynamic focusing probe;

[0024] **FIG. 7** shows a comparison between a macular section of a human globe in vitro, obtained by macroscopic histological imaging (right side) and an image arising from the process forming the subject of the invention (left side) where P represents the retinal folds, R the retina, S the sclera and V the vitreous humour;

[0025] **FIG. 8** is the image obtained from an anterior segment of a rabbit's eye, by the process forming the subject of the invention, where C represents the cornea, I the iris, S the sclera and Cr the anterior surface of the lens.

DETAILED DESCRIPTION OF THE INVENTION

[0026] According to a preferred embodiment of the process forming the subject of the invention, of which one system enabling its implementation is shown schematically in **FIG. 1**, the process consists in positioning an ultrasound probe **1** mounted within a head articulated in three dimensions X, Y, Z, at least one direction of which can be fixed, this head being steered by a servo-controlled positioning system **2**, controlled by a computer **3**, in particular in a direction perpendicular to the medium to be investigated.

[0027] This ultrasound probe **1** consists mainly of a transducer, in particular one made of PVDF (polyvinylidene difluoride), controlled by a transmitter/receiver **4**, in order to generate beams of convergent, broadband, ultrasonic waves, these waves being able to adopt a spherical or linear profile.

[0028] Next, **FIG. 2** shows an investigation of the posterior segment of an ocular globe **5**, previously inserted into a coupling medium **6** which does not impair the propagation of the waves, especially in the retina region. A probe **1** positioned on the pars plana **7** is used to avoid absorption of the ultrasound beam by the lens **8** (this lens also marking the boundary between the posterior segment **9** and the anterior segment **10** of an ocular globe **5**). This probe **1** transmits beams of ultrasound waves set within a nominal broadband frequency range varying from 30 to 100 MHz, involving wavelengths going from 50 to 15 μm, focused at a focal length of between 20 and 30 mm and preferably 25 mm, corresponding in fact to a focus at an average depth of an ocular globe.

[0029] For example, for a probe with a nominal frequency of 50 MHz, lateral and axial resolutions of 220 and 70 μm respectively are obtained at the focal length.

[0030] The receiving system will have a bandwidth adapted to the frequencies reflected by the structure, these frequencies being lower than the transmitted frequencies because of the attenuation by the medium which is crossed.

[0031] In order to investigate the anterior segment (cf. **FIG. 3**), this same probe **1** is used under the same control conditions as previously, in a position offset on the vertical axis (Z axis) at a distance corresponding in fact to the previous focal length.

[0032] According to another embodiment, the focal length, especially on the vertical penetration axis, is not modified by a mechanical servocontrol **2** in the position, but by an electronic or digital device steering the probe and able to modify, by careful command, the focusing area of the probe, in order thus to obtain simultaneously a high resolution image of the anterior segment and of the posterior segment of the eye. This probe, with dynamic focusing carried out by an electronic or digital control process, consists of a multi-element probe, with circular symmetry, made up of several concentric annular transducers evenly spaced over a plane surface or with spherical concavity (refer to **FIG. 4***a*). These transducers are independent of each other and are controlled individually in transmission and in reception by pulses which are offset in time (refer to **FIG. 4***b* which shows dynamic focusing obtained by introducing a phase difference—time delay—into the transmission between the various rings).

[0033] In transmission, the generated wavefront is convergent and its curvature is modified according to the distance between the structure investigated and the probe. The peripheral rings transmit first and the excitation of the central ring is the most retarded. Thus the focal length along the axis of the probe can be varied and is therefore determined by the phase difference or the time delay introduced between the various transducers. The same principle of dynamic focusing is used in reception: the electronic delay is adjusted to the depth of the echoes which arrive at that moment at the probe. In this way the depth of field is increased without in any way degrading the lateral resolution.

[0034] A measurement system, of which each of the components (digitizer **11**, computer **3**, control electronics **2**, transmitter/receiver **4**, etc.) forming it has a bandwidth compatible with the processing and analysis of the signals originating from the anterior segment and/or of the signals coming from the posterior segment of the eye, enables processing of the signals backscattered by the structure investigated. Thus, the backscattered ultrasound signal is amplified then digitized using the digitizer **11**, at a given sampling frequency (in particular of the order of 400 MHz over 8 bits).

[0035] This same computer controls the stepper on DC motors in order to move the probe and scan the ultrasound beams over the sample in a defined step along X and along Y in order to allow another measurement point or in an R,Ω step using a probe support head which allows an arciform scan.

[0036] For in vivo measurements and investigations, it is necessary, in order to get round the problem of parasitic movements of the eye in its orbit, to process the signal in real time and to have available an extremely fast and accurate probe movement system.

[0037] According to another characteristic, the computer is fitted with a module for processing the image and the radiofrequency signal. This module has programmed software which enables the two quantitative approaches, of 2D and/or 3D biometry and of tissue characterization, to be carried out.

[0038] The echographic signal can be shown in real time in the form of a A-scan line or in the form of a 2D image of the B-scan type. The B-scan images can display sections in the various planes parallel to the direction of propagation of the ultrasound (cf. **FIGS. 7 and 8**). A 2D image of the C-scan type can also be calculated in order to display sections in the plane perpendicular to the direction of propagation of the ultrasound. The C-scan is able to show sections located at different depths of the whole ocular globe.

[0039] The calculation and the reconstruction of the 3D image can be carried out using programmed mathematical functions specific to the ultrasound data to be processed.

[0040] Thus, provided the propagation speed of the ultrasound in the structures investigated is known, it is possible to determine morphological characteristics of these structures, especially their thickness and/or their volume.

[0041] The processing software of the radiofrequency signal enables a frequency analysis of the digitized and recorded backscattered signals to be made in order to calculate quantitative ultrasound parameters for the purpose of tissue characterization. These parameters are in particular the attenuation coefficient in dB/cm.MHz (decibels/cm-.megahertz), the overall attenuation coefficient in dB/cm, the backscatter coefficient in dB/cm.MHz and the overall backscatter coefficient in dB/cm.

[0042] These parameters can be estimated locally and their values can be shown in the form of images (parametric images).

[0043] It is of course possible to add other algorithms for processing the radiofrequency signal and the image, algorithms which could produce quantitative morphological and/or tissue information capable of characterizing the structures of the eye.

[0044] The images obtained by this investigation process, both for an ocular globe and the region of the anterior segment and the posterior segment, have a resolution which is improved by a factor of at least two to three compared with that obtained with conventional echographs and are not limited by the transparency of the media investigated as in particular with conventional optical investigation means (biomicroscopy, angiography) whose quality can be affected by the presence of cataracts and haemorrhages.

[0045] By way of example, **FIG. 7** illustrates the similarities between a histological image and an echographic image of the macula of a human eye (in vitro), and **FIG. 8** illustrates an image of an anterior segment of a rabbit's eye.

[0046] The process and the device which enables its implementation, such as those described previously, are not limited to applications in ophthalmology, but they can also find applications in gynaecology and obstetrics, in gastroenterology and in the field of cardio-vascular examinations and examinations by coelioscopy, or in dermatology and more generally in any medium which reflects a usable signal.

[0047] In particular, in the field of dermatology, it is possible, using the investigation and display process forming the subject of the invention, to investigate the various thicknesses of tissue forming the skin. Thus, it is possible for example, by processing the signal, to assess the degree of skin hydration, to evaluate healing of a tissue, to localize and investigate a tumour, and finally, more generally, to to open the way to examining a large number of pathologies currently encountered in dermatology.

[0048] The focus point or focusing area of the wave beam will be adjusted within a range going from a few tenths of a millimetre to several millimetres and the waveband used will be between 30 and 100 MHz.

[0049] It is of course understood that the present invention is not limited to the embodiments described and shown hereinbefore, but that it encompasses all the variants thereof.

1. A method for the investigation and display of tissues of human or animal origin in 2 or 3D, comprising the use of a probe with a fixed focusing area or a dynamic focusing area capable of generating beams of ultrasound, convergent waves in a nominal broad bandwidth, adapted to the frequencies reflected by the tissue investigated.

2. The method of claim 1, wherein said probe is a multi-element with circular symmetry, made up of several concentric annular transducers evenly spaced over a plane surface or with spherical concavity, said transducers being independent of each other and being controlled individually in transmission and in reception by pulses which are offset in time.

3. The method of claim 1, wherein the focal distance is modified by an electronic control process.

4. The method of claim 1, wherein the focal distance is modified by a numerical process.

5. The method according to claim 1, wherein the focal distance is adjusted to 20 to 30 mm to investigate the posterior segment.

6. The method according to claim 1, applicable in gynecology and obstetrics, in gastroenterology, in the field of cardiovascular examinations and examinations by coelioscopy, or in dermatology.

* * * * *

专利名称(译)	用于从高频超声探头探索和显示人或动物来源的组织的方法		
公开(公告)号	US20050251043A1	公开(公告)日	2005-11-10
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当前申请(专利权)人(译)	CENTRE法国国家科学研究		
[标]发明人	SAIED AMENA BERGER GENEVIEVE LAUGIER PASCAL PUECH MICHEL		
发明人	SAIED, AMENA BERGER, GENEVIEVE LAUGIER, PASCAL PUECH, MICHEL		
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外部链接	Espacenet USPTO		

摘要(译)

用于显示组织的扫描超声图像的方法采用包括安装到机械头的超声探头的装置。三维定位系统安装头部，用于将探针定位成与组织接近的正交关系。计算机控制三维定位系统，从而在扫描期间移动探针。该探头发射高频超声波，其标称频率包括在30至100MHz的范围内，并具有大的通带，适合于由组织反射的频率。超声波传输束在20至30mm的垂直穿透距离上聚焦在组织的给定区域中。获取并处理反射信号以供显示。