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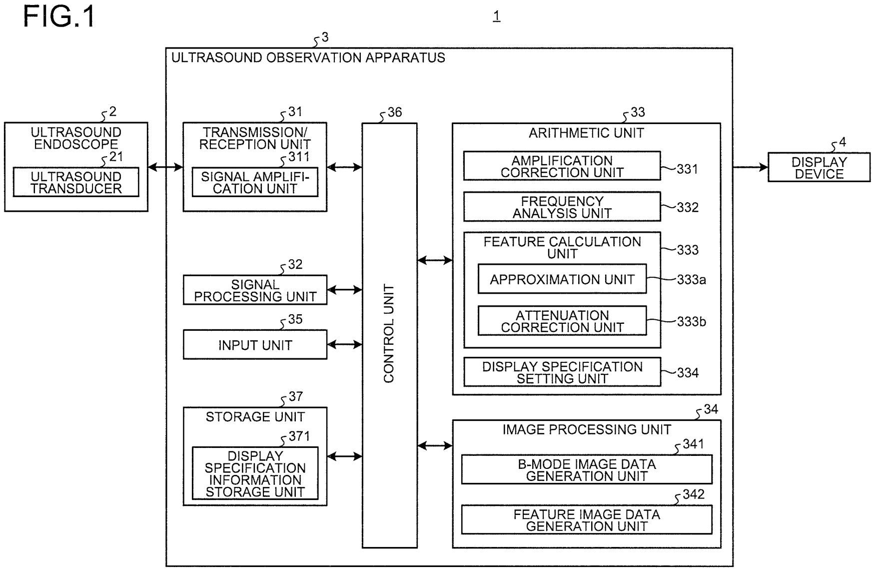
(54) ULTRASONIC OBSERVATION APPARATUS, OPERATION METHOD FOR ULTRASONIC OBSERVATION APPARATUS, AND OPERATION PROGRAM FOR ULTRASONIC OBSERVATION APPARATUS

(57) An ultrasound observation apparatus according to the present invention includes: a feature calculation unit that calculates a plurality of features on the basis of an ultrasound signal; a feature image data generation unit that generates feature image data in which features of a display target to be displayed together with an ultrasound image are colorized with a predetermined display specification in association with visual information among the plurality of features calculated by the feature calculation unit; and a display specification setting unit that sets the display specification of the feature of the display target on the basis of other feature other than the feature of the display target.

FIG.1



EP 3 366 220 A1

Description

Field

[0001] The present invention relates to an ultrasound observation apparatus for observing a tissue of an observation target using ultrasound, a method of operating an ultrasound observation apparatus, and an operation program for an ultrasound observation apparatus. Background

[0002] In some cases, ultrasound is applied in order to observe characteristics of living tissues or materials of an observation target. Specifically, ultrasound is transmitted to the observation target, and predetermined signal processing is applied to ultrasound echoes reflected by the observation target, so that information on features of the observation target is obtained.

[0003] As a technique for observing tissue characterization of an observation target such as a subject by using ultrasound, a technique for imaging a feature data of a frequency spectrum of a received ultrasound signal is known (for example, refer to Patent Document 1). In this technique, after extracting a feature data of a frequency spectrum as a quantity representing the tissue characterization of an observation target, a feature data image to which visual information corresponding to the feature data is attached is generated and displayed. A user such as a doctor diagnoses the tissue characterization of a specimen by viewing the displayed feature data image.

[0004] For example, in Patent Document 1, an elastic image in which the hardness of a tissue of an observation target is imaged is displayed, and color information to which a color is given according to a feature data is displayed. The elastic image is generally called an elastography, acquires information (feature data) on the hardness of the observation target in the set region, and superimposes color information corresponding to the feature data on the ultrasound image. Specifically, Patent Literature 1 discloses that an elastic image that is gradated on the basis of a relative ratio between a distortion at a measurement point of a measurement target and a distortion of a reference region is displayed as a reference to the distortion of the reference region selected within the image.

Citation List

Patent Literature

[0005] Patent Literature 1: JP 5160227 B2

Summary

Technical Problem

[0006] Herein, in the technique disclosed in Patent Document 1, the hardness is expressed by assigning relative color information to the feature data of the reference region with respect to the feature data to be displayed. For this reason, in some cases, depending on the feature data used to calculate the hardness, the range that can be expressed with color information becomes narrow, so that the difference in feature may not be expressed clearly.

[0007] An object of the present invention is to provide an ultrasound observation apparatus, a method of operating an ultrasound observation apparatus, and an operation program for an ultrasound observation apparatus capable of clearly expressing a difference in feature.

Solution to Problem

[0008] In order to solve the above described problem and achieve the object, an ultrasound observation apparatus according to the present invention generates an ultrasound image based on an ultrasound signal acquired by an ultrasound probe, the ultrasound probe including an ultrasound transducer configured to transmit ultrasound to an observation target and receive the ultrasound reflected from the observation target. The ultrasound observation apparatus includes a feature calculation unit configured to calculate a plurality of features based on the ultrasound signal; a feature image data generation unit configured to generate feature image data in which a feature of a display target to be displayed together with the ultrasound image, among the plurality of features calculated by the feature calculation unit, are colorized with a predetermined display specification; and a display specification setting unit configured to set a display specification of the feature of the display target based on other feature other than the feature of the display target.

[0009] In the ultrasound observation apparatus according to the present invention, the display specification setting unit is configured to set the display specification of the feature of the display target, based on a feature of a target region in an image based on the ultrasound signal which is the other feature.

[0010] In the ultrasound observation apparatus according to the present invention, the display specification setting unit is configured to set at least one of a colorization range of the feature of the display target and a change rate of hue of the feature of the display target by comparing a representative value of the other feature with a threshold value.

[0011] The ultrasound observation apparatus according to the present invention further includes a frequency analysis unit configured to analyze a frequency of a signal generated based on the ultrasound signal to calculate a plurality of frequency spectra. The feature calculation unit is configured to calculate a frequency feature based on a frequency spectrum calculated by the frequency analysis unit as one of the plurality of features.

[0012] In the ultrasound observation apparatus according to the present invention, the feature of the display target is any one of a sound velocity, a hardness, an attenuation amount, and the frequency feature, and the other feature is at least one feature different from the feature of the display target, among the sound velocity, the hardness, the attenuation amount, and the frequency feature.

[0013] In the ultrasound observation apparatus according to the present invention, the feature calculation unit is configured to linearly approximate the frequency spectrum calculated by the frequency analysis unit to calculate the frequency feature.

[0014] In the ultrasound observation apparatus according to the present invention, the frequency feature is at least one of a slope, an intercept and a mid-band fit obtained by approximating the frequency spectrum calculated by the frequency analysis unit.

[0015] The ultrasound observation apparatus according to the present invention further includes: a variation calculation unit configured to calculate a variation of each of the features; and a feature selection unit configured to select a feature of the display target based on the variation of each of the features calculated by the variation calculation unit. The display specification setting unit is configured to set a display specification of the feature of the display target based on other feature other than the feature of the display target selected by the feature selection unit.

[0016] A method of operating an ultrasound observation apparatus according to the present invention is a method of operating an ultrasound observation apparatus for generating an ultrasound image based on an ultrasound signal acquired by an ultrasound probe, the ultrasound including an ultrasound transducer configured to transmit ultrasound to an observation target and receive the ultrasound reflected from the observation target. The method includes: a feature calculating step of calculating, by a feature calculation unit, a plurality of features based on the ultrasound signal; a display specification setting step of setting, by a display specification setting unit, a display specification of a feature of a display target to be displayed together with the ultrasound image based on other feature other than the feature of the display target among the plurality of features calculated by the feature calculation unit; and a feature image data generating step of generating, by a feature image data generation unit, feature image data in which the feature of the display target is colorized with a predetermined display specification.

[0017] An operation program for an ultrasound observation apparatus according to the present invention is an operation program for an ultrasound observation apparatus for generating an ultrasound image based on an ultrasound signal acquired by an ultrasound probe, the ultrasound including an ultrasound transducer configured to transmit ultrasound to an observation target and receive the ultrasound reflected from the observation target. The operation program causes the ultrasound observation apparatus to execute: a feature calculation step of calculating, by a feature calculation unit, a plurality of features based on the ultrasound signal; a display specification setting step of setting, by a display specification setting unit, a display specification of a feature of a display target to be displayed together with the ultrasound image based on other feature other than the feature of the display target among the plurality of features calculated by the feature calculation unit; and a feature image data generation step of generating, by a feature image data generation unit, feature image data in which the feature of the display target is colorized with a predetermined display specification.

Advantageous Effects of Invention

[0018] According to the present invention, it is possible to clearly express a difference in feature.

Brief Description of Drawings

[0019]

FIG. 1 is a block diagram illustrating a configuration of an ultrasound observation system including an ultrasound observation apparatus according to a first embodiment of the present invention.

FIG. 2 is a diagram illustrating a relationship between a reception depth and an amplification factor in an amplification process performed by a signal amplification unit of the ultrasound observation apparatus according to the first embodiment of the present invention.

FIG. 3 is a diagram illustrating a relationship between a reception depth and an amplification factor in an amplification correction process performed by an amplification correction unit of the ultrasound observation apparatus according to the first embodiment of the present invention.

FIG. 4 is a diagram schematically illustrating a data arrangement in one sound ray of an ultrasound signal.

FIG. 5 is a diagram illustrating an example of a frequency spectrum calculated by a frequency analysis unit of the ultrasound observation apparatus according to the first embodiment of the present invention.

FIG. 6 is a diagram illustrating a straight line having a corrected feature corrected by an attenuation correction unit of the ultrasound observation apparatus according to the first embodiment of the present invention as a parameter.

FIG. 7 is a diagram illustrating a process executed by a display specification setting unit of the ultrasound observation apparatus according to the first embodiment of the present invention.

FIG. 8 is a flowchart illustrating an overview of processes performed by the ultrasound observation apparatus according to the first embodiment of the present invention.

FIG. 9 is a flowchart illustrating an overview of processes executed by a frequency analysis unit of the ultrasound observation apparatus according to the first embodiment of the present invention.

FIG. 10 is a diagram schematically illustrating a display example of feature images in a display device of the ultrasound observation apparatus according to the first embodiment of the present invention.

FIG. 11 is a diagram illustrating a process executed by a display specification setting unit of an ultrasound observation apparatus according to modified example 1 of the first embodiment of the present invention.

FIG. 12 is a diagram illustrating a process executed by a display specification setting unit of an ultrasound observation apparatus according to modified example 2 of the first embodiment of the present invention.

FIG. 13 is a diagram illustrating a process executed by a display specification setting unit of an ultrasound observation apparatus according to modified example 3 of the first embodiment of the present invention.

FIG. 14 is a block diagram illustrating a configuration of an ultrasound observation system including an ultrasound observation apparatus according to a second embodiment of the present invention.

FIG. 15 is a block diagram illustrating a configuration of an ultrasound observation system including an ultrasound observation apparatus according to a third embodiment of the present invention.

FIG. 16 is a diagram illustrating a process executed by a display specification setting unit of the ultrasound observation apparatus according to the third embodiment of the present invention.

Description of Embodiments

[0020] Hereinafter, modes for carrying out the present invention (hereinafter, referred to as "embodiments") will be described with reference to the accompanying drawings.

(First Embodiment)

[0021] FIG. 1 is a block diagram illustrating a configuration of an ultrasound observation system 1 including an ultrasound observation apparatus 3 according to a first embodiment of the present invention. The ultrasound observation system 1 illustrated in the figure is configured to include an ultrasound endoscope 2 (ultrasound probe) that transmits ultrasound to a subject as an observation target and receives the ultrasound reflected from the subject, the ultrasound observation apparatus 3 for generating an ultrasound image on the basis of the ultrasound signal acquired by the ultrasound endoscope 2, and a display device 4 for displaying the ultrasound image generated by the ultrasound observation apparatus 3.

[0022] The ultrasound endoscope 2 is configured to include, at the distal end portion of the ultrasound endoscope, an ultrasound transducer 21 for irradiating the subject with an ultrasound pulse (acoustic pulse) obtained by converting an electrical pulse signal received from the ultrasound observation apparatus 3 into the ultrasound pulse and converting an ultrasound echo reflected by the subject into an electrical echo signal (ultrasound signal) represented by voltage change and outputting the electrical echo signal. The ultrasound transducer 21 may be any of a convex oscillator, a linear oscillator, and a radial oscillator. In the ultrasound endoscope 2, the ultrasound transducer 21 may be allowed to mechanically scan, or a plurality of elements in the form of an array may be provided as the ultrasound transducer 21, and thus, the elements related to transmission and reception are electronically switched or transmission and reception of each element are delayed, so that the ultrasound transducer may be allowed to electronically scan.

[0023] Typically, the ultrasound endoscope 2 includes an imaging optical system and an imaging device, is inserted into a digestive tract (esophagus, stomach, duodenum, large intestine) or a respiratory organ (trachea / bronchus) of a subject and may capture the digestive tract, the respiratory organ and surrounding organs (pancreas, gallbladder, bile duct, biliary tract, lymph node, mediastinum, blood vessels, or the like). In addition, the ultrasound endoscope 2 is configured to include a light guide for guiding illumination light to be illuminated to the subject at the time of imaging. The distal end portion of the light guide reaches the distal end of the insertion portion of the ultrasound endoscope 2 to the subject, and the proximal end portion is connected to a light source device that generates the illumination light. In addition, the ultrasound endoscope is not limited to the ultrasound endoscope 2 and may be an ultrasound probe not including the imaging optical system and the imaging device.

[0024] The ultrasound observation apparatus 3 is configured to include a transmission/reception unit 31 electrically connected to the ultrasound endoscope 2 to transmit a transmission signal (pulse signal) configured with a high voltage pulse on the basis of a predetermined waveform and transmission timing to the ultrasound transducer 21 and to receive an echo signal as an electrical reception signal from the ultrasound transducer 21 to generate and output data of a digital high frequency (RF: Radio Frequency) signal (hereinafter, referred to as RF data), a signal processing unit 32 for generating digital B-mode reception data on the basis of the RF data received from the transmission/reception unit 31, an arithmetic unit 33 for performing predetermined arithmetic operation on the RF data received from the transmission/reception unit 31, an image processing unit 34 that generates various image data, an input unit 35 that is realized by using a user interface such as a keyboard, a mouse, a touch panel, or the like and receives input of various types of information, a control unit 36 for controlling the entire ultrasound observation system 1, and a storage unit 37 that stores various information necessary for operations of the ultrasound observation apparatus 3.

[0025] The transmission/reception unit 31 is configured to include a signal amplification unit 311 for amplifying the echo signal. The signal amplification unit 311 performs sensitivity time control (STC) correction that amplifies the echo signal having a larger reception depth with a higher amplification factor. FIG. 2 is a diagram illustrating the relationship between the reception depth and the amplification factor in the amplification process performed by the signal amplification unit 311. The reception depth z illustrated in FIG. 2 is a quantity calculated on the basis of the elapsed time from the reception start time point of the ultrasound. As illustrated in FIG. 2, when the reception depth z is smaller than the threshold value z_{th}, the amplification factor β (dB) is linearly increased from β_0 to β_{th} ($> \beta_0$) as the reception depth z is increased. In addition, when the reception depth z is equal to or larger than the threshold value z_{th}, a constant value β_{th} is taken as the amplification factor β (dB). The threshold value z_{th} is such a value that the ultrasound signal received from the observation target is almost attenuated and the noise becomes dominant. More generally, when the reception depth z is smaller than the threshold value z_{th}, the amplification factor β may be monotonically increased as the reception depth z is increased. In addition, the relationship illustrated in FIG. 2 is stored in advance in the storage unit 37.

[0026] The transmission/reception unit 31 performs processing such as filtering on the echo signal amplified by the signal amplification unit 311, performs A/D conversion to generate RF data in the time domain, and outputs the RF data to the signal processing unit 32 and the arithmetic unit 33. In addition, in a case where the ultrasound endoscope 2 has a configuration of allowing the ultrasound transducers 21 having a plurality of elements arranged in an array form to electronically scan, the transmission/reception unit 31 includes a multi-channel circuit for combining beams corresponding to the plurality of elements.

[0027] The frequency band of the pulse signal transmitted by the transmission/reception unit 31 is preferably set to a wide band which substantially covers the linear response frequency band of the electro-acoustic conversion of the pulse signal into the ultrasound pulse by the ultrasound transducer 21. In addition, the various processing frequency bands of the echo signal in the signal amplification unit 311 are preferably set to a wide band which substantially covers the linear response frequency band of the acoustic-electric conversion of the ultrasound echo into the echo signal by the ultrasound transducer 21. By these components, it is possible to carry out the approximation with high precision when executing an approximation process for the frequency spectrum to be described later.

[0028] The transmission/reception unit 31 has functions of transmitting various control signals outputted by the control unit 36 to the ultrasound endoscope 2 and receiving various types of information including ID for identification from the ultrasound endoscope 2 to transmit to the control unit 36.

[0029] The signal processing unit 32 performs known processing such as band pass filtering, envelope detection, and logarithmic conversion on the RF data to generate digital B-mode reception data. In logarithmic conversion, the common logarithm of the amount obtained by dividing RF data by reference voltage V_c is taken and expressed in decibel value. The signal processing unit 32 outputs the generated B-mode reception data to the image processing unit 34. The signal processing unit 32 is realized by using a central processing unit (CPU), various arithmetic circuits, and the like.

[0030] The arithmetic unit 33 is configured include an amplification correction unit 331 that performs amplification correction so that the amplification factor β (dB) is constant regardless of the reception depth z with respect to the RF data generated by the transmission/reception unit 31, a frequency analysis unit 332 for performing frequency analysis by applying a fast Fourier transform (FFT) to the RF data which is amplified and corrected to calculate a frequency spectrum, a feature calculation unit 333 for calculating the feature of the frequency spectrum on the basis of the frequency spectrum calculated by the frequency analysis unit 332, a display specification setting unit 334 for setting the display specification of the feature to be displayed on the basis of the feature different from the feature of the display target to be displayed on the display device 4. The arithmetic unit 33 is realized by using a CPU, various operation circuits, and the like.

[0031] FIG. 3 is a diagram illustrating a relationship between a reception depth and an amplification factor in the amplification correction process performed by the amplification correction unit 331. As illustrated in FIG. 3, the amplification factor β in the amplification correction process performed by the amplification correction unit 331 has a maximum value β_{th}-β_0 when the reception depth z is zero, the amplification factor is linearly decreased until the reception depth z reaches the threshold value z_{th} from zero, and the amplification factor is zero when the reception depth z is equal to or larger than the threshold value z_{th}. The amplification correction unit 331 amplifies and corrects the digital RF signal according to the amplification factor β determined in this manner, so that it is possible to offset the influence of the STC correction in the signal processing unit 32 and output a signal with a constant amplification factor β_{th}. The relationship between the reception depth z and the amplification factor β performed by the amplification correction unit 331 varies according to the relationship between the reception depth and the amplification factor in the signal processing unit 32.

[0032] The reason for performing such amplification correction will be described. The STC correction is a correction process for eliminating the influence of attenuation from the amplitude of the analog signal waveform by amplifying the amplitude of the analog signal waveform uniformly over the entire frequency band and with an amplification factor monotonically increasing with respect to the depth. For this reason, in the case of generating a B-mode image in which the amplitude of the echo signal is converted into luminance to display and in the case of scanning a uniform tissue, the luminance value is constant regardless of the depth by performing the STC correction. Namely, it is possible to obtain the effect of eliminating the influence of attenuation from the luminance value of the B-mode image.

[0033] On the other hand, as in the embodiment, in the case of using the result of calculating and analyzing the frequency spectrum of the ultrasound, it is not possible to precisely eliminate the influence of the attenuation accompanying the propagation of the ultrasound even by the STC correction. This is because, in general, the attenuation varies depending on the frequency (refer to the Equation (1) described later), but the amplification factor of the STC correction varies depending only on the distance, and there is no frequency dependency.

[0034] In order to solve the above-mentioned problem, namely, the problem that, in the case of using the result of calculating and analyzing the frequency spectrum of ultrasound, it is not possible to precisely eliminate the influence of attenuation accompanying the propagation of ultrasound even with STC correction, it is considered to output a reception signal subjected to the STC correction at the time of generating a B-mode image and to perform new transmission different from the transmission for generating the B-mode image and output a reception signal that has not been subjected to the STC correction at the time of generating an image based on the frequency spectrum. However, in this case, there is a problem that the frame rate of the image data generated on the basis of the reception signal is lowered.

[0035] Therefore, in the embodiment, in order to eliminate the influence of the STC correction on the signal subjected to the STC correction for the B-mode image while maintaining the frame rate of the generated image data, the amplification correction unit 331 performs the correction of the amplification factor.

[0036] The frequency analysis unit 332 samples the RF data (line data) of each sound ray amplified and corrected by the amplification correction unit 331 at predetermined time intervals to generate sample data. The frequency analysis unit 332 calculates a frequency spectrum at a plurality of positions (data positions) on the RF data by applying an FFT process to the sample data group. The term "frequency spectrum" as used herein denotes "frequency distribution of intensity at a certain reception depth z" obtained by applying the FFT process on a sample data group. In addition, the term "intensity" as used herein denotes, for example, a parameter such as a voltage of an echo signal, a power of an echo signal, a sound pressure of an ultrasound echo, or acoustic energy of an ultrasound echo, amplitude or time integral value of the parameters, or a combination thereof.

[0037] In general, in a case where the observation target is a living tissue, the frequency spectrum tends to vary depending on the characterization of the living tissue scanned with ultrasound. This is because the frequency spectrum has a correlation with the size, number density, acoustic impedance, or the like of the scatterer which scatters the ultrasound. "The characterization of the living tissue" referred to herein denotes, for example, malignant tumor (cancer), benign tumor, endocrine tumor, mucous tumor, normal tissue, cyst, vascular, and the like.

[0038] FIG. 4 is a diagram schematically illustrating a data arrangement in one sound ray of an ultrasound signal. In the sound ray SR_k illustrated in the figure, a white or black rectangle denotes data at one sample point. In addition, in the sound ray SR_k, the data located on the right side is sample data from a deep portion measured from the ultrasound transducer 21 along the sound ray SR_k (refer to the arrow in FIG. 4). The sound ray SR_k is discretized at a time interval corresponding to the sampling frequency (for example, 50 MHz) in the A/D conversion performed by the transmission/reception unit 31. FIG. 4 illustrates a case where the eighth data position of the sound ray SR_k with the number k is set as the initial value $Z^{(k)}_0$ in the direction of the reception depth z, but the position of the initial value may be arbitrarily set. The calculation result by the frequency analysis unit 332 is obtained as a complex number and stored in the storage unit 37.

[0039] The data group F_j (j = 1, 2, ..., K) illustrated in FIG. 4 is a sample data group to be subjected to the FFT process. In general, in order to perform the FFT process, it is necessary for the sample data group to have data number of power of 2. In this sense, the sample data group F_j (j = 1, 2, ..., K-1) is a normal data group having the number of data being 16 (= 2^4). On the other hand, the sample data group F_K has the number of data being 12, and thus, the sample data group F_K is an abnormal data group. When the FFT process is to be performed on an abnormal data group, a process for generating a normal sample data group by inserting zero data corresponding to the shortage is performed. This point will be described in detail in the process of the frequency analysis unit 332 (refer to FIG. 9) .

[0040] FIG. 5 is a diagram illustrating an example of the frequency spectrum calculated by the frequency analysis unit 332. In FIG. 5, the horizontal axis represents the frequency f. In addition, in FIG. 5, the vertical axis represents a common logarithm (decibel expression) $I = 10 \log_{10} (I_0 / I_c)$ of an amount obtained by dividing an intensity I_0 by a reference intensity

I_c (constant). A straight line L_{10} illustrated in FIG. 5 will be described later. In the embodiment, curves and straight lines are configured with discrete sets of points.

[0041] In the frequency spectrum C_1 illustrated in FIG. 5, a lower limit frequency f_L and an upper limit frequency f_H of the frequency band used for the subsequent arithmetic operation are parameters determined on the basis of the frequency band of the ultrasound transducer 21, the frequency band of the pulse signal transmitted by the transmission/reception unit 31, or the like. Hereinafter, in FIG. 5, the frequency band determined by the lower limit frequency f_L and the upper limit frequency f_H is referred to as a "frequency band F".

[0042] The feature calculation unit 333 calculates features of a plurality of frequency spectra in the set region of interest (ROI). The feature calculation unit 333 is configured include an approximation unit 333a that calculates a feature of a frequency spectrum (hereinafter, referred to as a pre-correction feature) before performing an attenuation correction process by approximating the frequency spectrum with a straight line and an attenuation correction unit 333b that calculates a feature by performing an attenuation correction process on the pre-correction feature calculated by the approximation unit 333a.

[0043] The approximation unit 333a performs a regression analysis of the frequency spectrum in a predetermined frequency band and approximates the frequency spectrum with a linear equation (regression line) to calculate the pre-correction feature featuring the approximated linear equation. For example, in the case of the frequency spectrum C_1 illustrated in FIG. 5, the approximation unit 333a obtains the regression line L_{10} by performing a regression analysis in the frequency band F and approximating the frequency spectrum C_1 by a linear equation. In other words, the approximation unit 333a calculates, as the pre-correction feature, a mid-band fit $c_0 = a_0 f_M + b_0$ which is a value on the regression line L_{10} having slope a_0 of the regression line, intercept b_0, and center frequency $f_M = (f_L + f_H) / 2$ of the frequency band F.

[0044] Among the three pre-correction features, the slope a_0 has a correlation with the size of the scatterer of the ultrasound, and it is generally considered that the larger the scatterer, the smaller the slope. The intercept b_0 has a correlation with the size of the scatterer, a difference in acoustic impedance, the number density (concentration) of the scatterers, and the like. Specifically, it is considered that the intercept b_0 has a larger value as the size of the scatterer is larger, has a larger value as the difference in acoustic impedance is larger, and has a larger value as the number density of the scatterers is larger. The mid-band fit c_0 is an indirect parameter derived from the slope a_0 and the intercept b_0 and gives the intensity of the spectrum at the center within the effective frequency band. For this reason, it is considered that the mid-band fit c_0 has a certain degree of correlation with luminance of the B-mode image in addition to the size of the scatterer, a difference in acoustic impedance, and the number density of the scatterers. In addition, the feature calculation unit 333 may approximate the frequency spectrum with a polynomial of second or higher order by regression analysis.

[0045] The correction performed by the attenuation correction unit 333b will be described. In general, the attenuation amount A (f, z) of the ultrasound is an attenuation occurring while the ultrasound reciprocates between the reception depth 0 and the reception depth z, the attenuation amount is defined as a change in intensity before and after the reciprocation (a difference in decibel expression). It is empirically known that the attenuation amount A (f, z) is proportional to the frequency in a uniform tissue and is expressed by the following Equation (1).

$$A(f, z) = 2\alpha z f \tag{1}$$

[0046] Herein, the proportional constant α is an amount called an attenuation factor. In addition, z is the reception depth of the ultrasound, and f is the frequency. A specific value of the attenuation factor α is determined depending on a portion of a living body when the observation target is the living body. The unit of the attenuation factor α is, for example, dB / cm / MHz. In addition, in the embodiment, it is possible to change the value of the attenuation factor α by the input from the input unit 35.

[0047] The attenuation correction unit 333b performs the attenuation correction on the pre-correction features (slope a_0, intercept b_0, and mid-band fit c_0) extracted by the approximation unit 333a according to the following equations (2) to (4) to calculate features "a", "b", and "c".

$$a = a_0 + 2\alpha z \tag{2}$$

$$b = b_0 \tag{3}$$

$$c = c_0 + A(f_M, z) = c_0 + 2\alpha z f_M \quad (= a f_M + b) \tag{4}$$

[0048] As apparent from the equations (2) and (4), the attenuation correction unit 333b performs the correction with a larger correction amount as the reception depth z of ultrasound is larger. In addition, according to the Equation (3), the correction on the intercept is the identity transformation. This is because the intercept is a frequency component corresponding to frequency 0 (Hz) and is not influenced by the attenuation.

[0049] FIG. 6 is a diagram illustrating a straight line having the features "a", "b", and "c" calculated by the attenuation correction unit 333b as parameters. The equation of the straight line L_1 is expressed as follows.

$$I = af + b = (a_0 + 2\alpha z)f + b_0 \qquad (5)$$

[0050] As apparent from the Equation (5), the straight line L_1 has a larger slope ($a > a_0$) and the same intercept ($b = b_0$) in comparison with the straight line L_{10} before the attenuation correction.

[0051] The display specification setting unit 334 sets the display specification of the feature to be displayed on the basis of the features different from the features of the display target to be displayed on the display device 4. Specifically, in the first embodiment, the display specification setting unit 334 sets the hue scale, which is the display specification of the feature "a" indicating the slope, on the basis of the feature "c" indicating the mid-band fits. The hue scale referred to in this description denotes that colors (hues) having different light wavelengths are arranged in a continuous manner (including multiple steps) and the hues and the values of the features are associated with each other. In FIG. 7, the closer to the left, the closer to red; and the closer to the right, the closer to blue. Specifically, from the left, red, orange, yellow, green, and blue are arranged in the descending order of the wavelength of visible light. For example, the shortest wavelength is 380 nm and the longest wavelength is 750 nm. FIG. 7 is a diagram illustrating a process executed by the display specification setting unit 334 of the ultrasound observation apparatus 3 according to the first embodiment of the present invention. In FIG. 7, the horizontal axis represents the feature "a". In addition, in FIG. 7, the vertical axis represents the feature "c". FIG. 7 is a graph illustrating a distribution of the feature "a" and the feature "c".

[0052] As illustrated in FIG. 7, the distribution of the feature "a" and the feature "c" differs depending on the type of the characterization of the living tissue (hereinafter, referred to as a tissue characterization). For example, certain tissue characterization is distributed in region Q_1, and other tissue characterization is distributed in region Q_2. In this case, when the feature "a" is expressed with the same hue scale, although one tissue characterization is clearly expressed according to the value of the feature "a", the difference in the value of the feature "a" is not clearly expressed in the other tissue characterization, or the value of the feature "a" is distributed in an region deviated from the hue scale and the feature "a" is not displayed.

[0053] In the first embodiment, the display specification setting unit 334 sets the display specification of the feature "a" of a display target on the basis of the feature "c". Specifically, the display specification setting unit 334 obtains the average value of the plurality of features "c" calculated by the feature calculation unit 333, for example, the average value of the features in the set region of interest, compares the average value with a threshold value c_{th}, and sets the hue scale on the basis of the comparison result. For example, when the average value of the feature "c" is smaller than the threshold value c_{th}, the display specification setting unit 334 sets the hue scale to a hue scale CB_1. On the other hand, when the average value of the feature "c" is equal to or larger than the threshold value c_{th}, the display specification setting unit 334 sets the hue scale to a hue scale CB_2 having a different colorization range from the hue scale CB_1. In this manner, by setting the hue scale of the feature "a" on the basis of the feature "c", it is possible to set the hue scale corresponding to the tissue characterization according to a distribution of the feature "a" and the feature "c".

[0054] The image processing unit 34 is configured to include a B-mode image data generation unit 341 for generating B-mode image data which is an ultrasound image to be displayed by converting the amplitude of the echo signal into the luminance and a feature image data generation unit 342 for generating feature image data in which the feature calculated by the attenuation correction unit 333b is displayed together with the B-mode image in association with visual information.

[0055] The B-mode image data generation unit 341 generates the B-mode image data by performing signal processing by using known techniques such as gain processing and contrast processing on the B-mode reception data received from the signal processing unit 32 and by performing data thinning according to the data step width determined according to the display range of the image in the display device 4. The B-mode image is a grayscale image in which the values of R (red), G (green), and B (blue) which are variables when adopting a RGB color system as a color space are matched.

[0056] The B-mode image data generation unit 341 performs coordinate transformation for rearranging the B-mode reception data from the signal processing unit 32 so that the scanning range can be spatially correctly expressed and, after that, performs interpolation between the B-mode reception data to fill gaps between the B-mode reception data and generate the B-mode image data. The B-mode image data generation unit 341 outputs the generated B-mode image data to the feature image data generation unit 342.

[0057] The feature image data generation unit 342 generates feature image data by superimposing visual information relating to the features calculated by the feature calculation unit 333 on each pixel of the image in the B-mode image data. The feature image data generation unit 342 allocates, for example, to a pixel region corresponding to the data amount of one sample data group F_j (j = 1, 2 ..., K) illustrated in FIG. 4, visual information corresponding to the feature of the frequency spectrum calculated from the sample data group F_j. For example, the feature image data generation unit 342 generates feature image data by associating the hue as the visual information with any one of the above-described slope, intercept, and mid-band fit. Specifically, in the case of associating the hue as the visual information with the feature "a", the feature image data generation unit 342 allocates the visual information by referring to the hue scale set by the display specification setting unit 334. As the visual information relating to the feature, in addition to the hue, for example, there may be exemplified variables of a color space constituting a predetermined color system such as saturation, brightness, luminance value, R (red), G (green), and B (blue).

[0058] The control unit 36 is realized by using a CPU (Central Processing Unit) having arithmetic and control functions, various arithmetic circuits, and the like. The control unit 36 reads the information stored and retained by the storage unit 37 from the storage unit 37 and executes various arithmetic processes relating to a method of operating the ultrasound observation apparatus 3, so as to control overall of the ultrasound observation apparatus 3. It is also possible to configure the control unit 36 by using the CPU and the like common to the signal processing unit 32 and the arithmetic unit 33.

[0059] The storage unit 37 stores the plurality of features calculated for each frequency spectrum by the attenuation correction unit 333b and the image data generated by the image processing unit 34. In addition, the storage unit 37 is configured to include a display specification information storage unit 371 that stores a distribution of two features out of the plurality of features as illustrated in FIG. 7, a threshold value for performing allocating and setting the hue scale in the distribution, and the plurality of hue scales for each combination of the features.

[0060] In addition to the above, the storage unit 37 stores, for example, information necessary for the amplification process (relationship between the amplification factor and the reception depth illustrated in FIG. 2), information necessary for the amplification correction process (relationship between the amplification factor and the reception depth illustrated in FIG. 3), information necessary for the attenuation correction process (refer to the Equation (1)), Information relating to window function (Hamming, Hanning, Blackman, or the like) necessary for the frequency analysis process, and the like.

[0061] In addition, the storage unit 37 stores various programs including an operation program for executing the method of operating the ultrasound observation apparatus 3. The operation program may also be recorded on a computer-readable recording medium such as a hard disk, a flash memory, a CD-ROM, a DVD-ROM, or a flexible disk and distributed widely. In addition, the above-described various programs may also be acquired by downloading via a communication network. The communication network referred to herein is realized by, for example, an existing public line network, a local area network (LAN), a wide area network (WAN), and the like and may be wired or wireless.

[0062] The storage unit 37 having the above configuration is realized by using a read only memory (ROM) in which various programs and the like are preliminarily installed, a random access memory (RAM) for storing arithmetic parameters and data of each process, and the like.

[0063] FIG. 8 is a flowchart illustrating the overview of the processes performed by the ultrasound observation apparatus 3 having the above configuration. First, the ultrasound observation apparatus 3 receives an echo signal as a measurement result of an observation target by the ultrasound transducer 21 from the ultrasound endoscope 2 (Step S1).

[0064] Upon receiving the echo signal from the ultrasound transducer 21, the signal amplification unit 311 amplifies the echo signal (Step S2). Herein, for example, the signal amplification unit 311 performs amplification (STC correction) of the echo signal on the basis of the relationship between the amplification factor and the reception depth illustrated in FIG. 2.

[0065] Subsequently, the B-mode image data generation unit 341 generates the B-mode image data by using the echo signal amplified by the signal amplification unit 311 and outputs the B-mode image data to the display device 4 (Step S3). Upon receiving the B-mode image data, the display device 4 displays the B-mode image corresponding to the B-mode image data (Step S4).

[0066] The amplification correction unit 331 performs amplification correction on the signal output from the transmission/reception unit 31 so that the amplification factor is constant regardless of the reception depth (Step S5). Herein, for example, the amplification correction unit 331 performs amplification correction such that the relationship between the amplification factor and the reception depth illustrated in FIG. 3 is established.

[0067] After that, the frequency analysis unit 332 calculates frequency spectra for all the sample data groups by performing the frequency analysis by the FFT process (Step S6: frequency analysis step). FIG. 9 is a flowchart illustrating the overview of the processing executed by the frequency analysis unit 332 in Step S6. Hereinafter, the frequency analysis process will be described in detail with reference to the flowchart illustrated in FIG. 9.

[0068] First, the frequency analysis unit 332 sets the counter k for identifying the sound ray of the analysis target as k_0 (Step S21).

[0069] Subsequently, the frequency analysis unit 332 sets an initial value $Z^{(k)}{}_0$ of a data position (corresponding to a reception depth) $Z^{(k)}$ representing a series of the data groups (sample data group) acquired for the FFT process (step S22). For example, FIG. 4 illustrates a case where the eighth data position of the sound ray SR_k is set as the initial value

$Z^{(k)}_0$ as described above.

[0070] After that, the frequency analysis unit 332 acquires the sample data group (Step S23), and applies the window function stored in the storage unit 37 to the acquired sample data group (Step S24). In this manner, by applying the window function to the sample data group, it is possible to prevent the sample data group from becoming discontinuous at the boundary and to prevent artifacts from occurring.

[0071] Subsequently, the frequency analysis unit 332 determines whether or not the sample data group at the data position $Z^{(k)}$ is a normal data group (Step S25). As described with reference to FIG. 4, the sample data group needs to have a data number of a power of 2. Hereinafter, the number of data of the normal sample data group is 2^n (n is a positive integer). In the embodiment, the data position $Z^{(k)}$ is set to be the center of the sample data group to which $Z^{(k)}$ belongs as much as possible. Specifically, since the number of data of the sample data group is 2^n, $Z^{(k)}$ is set to the $2^n/2$ (= 2^{n-1}) -th position close to the center of the sample data group. In this case, the fact that the sample data group is normal denotes that there are $2^{n-1}-1$ (= N) data before the data position $Z^{(k)}$ and there are 2^{n-1} (= M) data after the data position $Z^{(k)}$. In the case illustrated in FIG. 4, the sample data groups F_1, F_2, F_3, ..., and F_{K-1} are normal. In addition, in FIG. 4, the case of n = 4 (N = 7, M = 8) is exemplified.

[0072] As a result of the determination in Step S25, in a case where the sample data group at the data position $Z^{(k)}$ is normal (Step S25: Yes), the frequency analysis unit 332 proceeds to Step S27 described later.

[0073] As a result of the determination in Step S25, in a case where the sample data group at the data position $Z^{(k)}$ is not normal (Step S25: No), the frequency analysis unit 332 generates a normal sample data group by inserting zero data corresponding to the shortage (step S26). In the sample data group (for example, the sample data group F_K in FIG. 4) that is determined not to be normal in Step S25, the window function is applied before adding the zero data. For this reason, no data discontinuity occurs even if the zero data is inserted into the sample data group. After Step S26, the frequency analysis unit 332 proceeds to Step S27 to be described later.

[0074] In Step S27, the frequency analysis unit 332 performs the FFT process by using the sample data group to obtain a frequency spectrum which is the frequency distribution of amplitude (Step S27).

[0075] Subsequently, the frequency analysis unit 332 changes the data position $Z^{(k)}$ by the step width D (Step S28). It is assumed that the storage unit 37 previously stores the step width D. In FIG. 4, the case of D = 15 is exemplified. It is desirable that the step width D is allowed to coincide with the data step width used by the B-mode image data generation unit 341 at the time of generating the B-mode image data. However, in a case where it is desired to reduce the arithmetic amount in the frequency analysis unit 332, a value larger than the data step width may be set as the width D.

[0076] After that, the frequency analysis unit 332 determines whether or not the data position $Z^{(k)}$ is larger than the maximum value $Z^{(k)}_{max}$ on the sound ray SR_k (Step S29). In a case where the data position $Z^{(k)}$ is larger than the maximum value $Z^{(k)}_{max}$ (Step S29: Yes), the frequency analysis unit 332 increments the counter k by 1 (Step S30). This denotes that the process is shifted to an adjacent sound ray. On the other hand, in a case where the data position $Z^{(k)}$ is equal to or smaller than the maximum value $Z^{(k)}_{max}$ (Step S29: No), the frequency analysis unit 332 returns to Step S23. In this manner, the frequency analysis unit 332 performs the FFT process on $[(Z^{(k)}_{max} - Z^{(k)}_0 + 1) / D + 1]$ sample data groups on the sound ray SR_k. Herein, [X] represents the largest integer not exceeding X.

[0077] After Step S30, the frequency analysis unit 332 determines whether or not the counter k is larger than the maximum value k_{max} (Step S31). In a case where the counter k is larger than the maximum value k_{max} (Step S31: Yes), the frequency analysis unit 332 ends a series of the frequency analysis processes. On the other hand, in a case where the counter k is equal to or smaller than the maximum value k_{max} (Step S31: No), the frequency analysis unit 332 returns to Step S22. The maximum value k_{max} is set to a value arbitrarily entered by the user such as a doctor through the input unit 35 or set in advance in the storage unit 37.

[0078] In this manner, the frequency analysis unit 332 performs the FFT process multiple times for each of ($k_{max} - k_0 + 1$) sound rays within the analysis target region. The result of the FFT process is stored in the storage unit 37 together with the reception depth and the reception direction.

[0079] In addition, in the above description, the frequency analysis process is performed on all the regions in which the frequency analysis unit 332 has received the ultrasound signal. However, the frequency analysis process may also be performed only within the set region of interest.

[0080] Following the frequency analysis process in Step S6 described above, the feature calculation unit 333 calculates the respective pre-correction features of the plurality of frequency spectra and performs the attenuation correction for eliminating the influence of the attenuation of ultrasound on the pre-correction feature of each frequency spectrum to calculate the corrected feature of each frequency spectrum (Steps S7 to S8: feature calculation step).

[0081] In Step S7, the approximation unit 333a performs the regression analysis on each of the frequency spectra generated by the frequency analysis unit 332 to calculate the pre-correction feature corresponding to each frequency spectrum (Step S7). Specifically, the approximation unit 333a approximates each frequency spectrum with a linear equation by performing the regression analysis and calculates the slope a_0, the intercept b_0, and the mid-band fit c_0 as pre-correction features. For example, the straight line L_{10} illustrated in FIG. 5 is a regression line approximated by the approximation unit 333a to the frequency spectrum C_1 of the frequency band F by performing the regression analysis.

[0082] Subsequently, the attenuation correction unit 333b calculates the corrected feature by performing the attenuation correction on the pre-correction feature approximated to each frequency spectrum by the approximation unit 333a by using the attenuation factor α and stores the calculated corrected feature in the storage unit 37 (Step S8). The straight line L_1 illustrated in FIG. 6 is an example of a straight line obtained by the attenuation correction unit 333b performing the attenuation correction process.

[0083] In Step S8, the attenuation correction unit 333b calculates the corrected feature by inserting the data position $Z = (f_{sp} / 2v_s)$ Dn obtained by using the data array of the sound rays of ultrasound signal at the reception depth z in the equations (2) and (4). Herein, f_{sp} is the data sampling frequency, v_s is the sound velocity, D is the data step width, and n is the number of data steps from the first data of the sound ray to the data position of the sample data group to be processed. For example, if the data sampling frequency f_{sp} is assumed to be 50 MHz, the sound velocity v_s is assumed to be 1530 m/sec, and the data arrangement illustrated in FIG. 4 is adopted so that the step width D is 15, z = 0.2295 n (mm).

[0084] After that, for each pixel in the B-mode image data generated by the B-mode image data generation unit 341, on the basis of a feature different from the feature to be displayed, among the features calculated in Step S8, the display specification (hue scale) of the feature of the display target is set (Step S9: display specification setting step). For example, a hue scale that is a display specification of the feature "a" indicating the slope is set on the basis of the feature "c" indicating the mid-band fit.

[0085] For each pixel in the B-mode image data generated by the B-mode image data generation unit 341, the feature image data generation unit 342 generates feature image data by superimposing the visual information (for example, hue) which is visual information associated with the feature calculated in Step S8 by using the hue scale that has been set in Step S9 (Step S10: feature image data generation step).

[0086] After that, under the control of the control unit 36, the display device 4 displays a feature image corresponding to the feature image data generated by the feature image data generation unit 342 (Step S11). FIG. 10 is a diagram schematically illustrating a display example of a feature image on the display device 4. A feature image 201 illustrated in the figure has a superimposed image display portion 202 for displaying an image in which visual information on a feature is superimposed on a B-mode image and an information display portion 203 for displaying identification information or the like of the observation target. In addition, the information display portion 203 may further display information of feature, information of approximate equation, image information such as gain and contrast, and the like. In addition, the B-mode image corresponding to the feature image may be displayed side by side with the feature image.

[0087] In the above-described series of processes (Steps S1 to S11), the process of Step S2 and the processes of Steps S4 to S11 may be performed in parallel.

[0088] According to the first embodiment of the present invention described above, the display specification setting unit 334 is configured to set the display specification of the feature "a" of the display target on the basis of the feature "c" different from the feature "a" of the display target to be displayed on the display device 4, so that it is possible to clearly express the difference of the feature by selecting the optimal hue scale from the distribution of the two features.

[0089] In addition, in the first embodiment, although it has been described that the display specification setting unit 334 sets the display specification of the feature of the display target on the basis of the average value of the feature different from the feature of the display target to be displayed on the display device 4, the present invention is not limited thereto, and the hue scale may be set on the basis of a mode value or a median value.

[0090] In addition, in the above-described first embodiment, for example, in a case where it is difficult to perform determination by using only one threshold value due to such as region overlapping between tissue characterization in the distribution of the feature "a" and the feature "c", a selection range of the hue scale to be set is set in advance for each region, and the display specification setting unit 334 may set the display specification of the feature of the display target by determining which selection range includes the average value of the feature different from the feature of the display target to be displayed on the display device 4.

(Modified Example 1 of First Embodiment)

[0091] FIG. 11 is a diagram illustrating a process executed by the display specification setting unit 334 of the ultrasound observation apparatus 3 according to modified example 1 of the first embodiment of the present invention. In the above-described first embodiment, it has been described that one-end sides of the hue scales are aligned, for example, that the minimum value of the feature "a" is set to zero [dB/MHz] (refer to FIG. 7). However, the values at both ends of the respective hue scales may be different. For example, the display specification setting unit 334 may set the hue scale CB_3 of which range (colorization range) of the value of the feature "a" is 0 to 4 [dB/MHz] as illustrated in (a) of FIG. 11 and the hue scale CB_4 of which range of the value of the feature "a" is 1 to 3 [dB/MHz] as illustrated in (b) of FIG. 11 so as to be set in accordance with the value of the feature "c". At this time, the display specification setting unit 334 compares the representative value (for example, the average value or the mode value) of the feature "c" with the threshold value and sets the colorization range on the basis of the comparison result.

(Modified Example 2 of First Embodiment)

[0092] FIG. 12 is a diagram illustrating a process executed by the display specification setting unit 334 of the ultrasound observation apparatus 3 according to modified example 2 of the first embodiment of the present invention. In the above-described first embodiment, it has been described that the hue scales having different colorization ranges of the value of the feature "a" and having the same proportion of the change rate of the hue (refer to FIG. 7) are used. However, the hue scales may have different change rates of the hue. For example, as illustrated in (a) of FIG. 12 and (b) of FIG. 12, the display specification setting unit 334 may set the hue scale CB_5 and the hue scale CB_6 having the same range of the value of the feature "a" being 0 to 4 dB/MHz and having different change rate of the gradation of the hue in accordance with the value of the feature "c". At this time, the display specification setting unit 334 compares the representative value (for example, the average value or the mode value) of the feature "c" with the threshold value and sets the change rate of the hue on the basis of the comparison result.

(Modified Example 3 of First Embodiment)

[0093] FIG. 13 is a diagram illustrating a process executed by the display specification setting unit 334 of the ultrasound observation apparatus 3 according to modified example 3 of the first embodiment of the present invention. In the above-described first embodiment, it has been described that the display specification setting unit 334 sets the hue scale according to the value of the feature "c" in the region of interest. However, the hue scale may be set according to the value of the feature "c" of the target site in the region of interest. For example, the display specification setting unit 334 sets the hue scale according to the value of the feature "c" on the target site S such as a tumor in the region of interest R as illustrated in FIG. 13. In modified example 3, for example, the hue scale is set according to the value of the feature "c" at the position within the target site S selected by the user through the input unit 35. As a result, the hue scale is allowed to be set on the basis of the feature corresponding to the visual information, so that it is possible to perform more highly accurate display of the feature of the display target.

[0094] In addition to the value of the feature in the region of interest, the value of the feature at the position in the target site selected by the user through the input unit 35, the value of the feature of the entire B-mode image may be used.

(Second Embodiment)

[0095] FIG. 14 is a block diagram illustrating a configuration of an ultrasound observation system 1a including an ultrasound observation apparatus 3a according to a second embodiment of the present invention. The ultrasound observation system 1a illustrated in the figure is configured include the ultrasound observation apparatus 3a instead of the ultrasound observation apparatus 3 of the ultrasound observation system 1 according to the above-described first embodiment. In above-described first embodiment, it has been described that the display specification setting unit 334 sets the hue scale of the feature which is set in advance. However, in the second embodiment, the feature is selected, and the hue scale is set according to a variation of the feature.

[0096] An arithmetic unit 33a of the ultrasound observation apparatus 3a is configured include a variation calculation unit 335 and a feature selection unit 336 in addition to the configuration of the arithmetic unit 33 described above. The variation calculation unit 335 calculates variations in the plurality of corrected features calculated by the feature calculation unit 333. Specifically, in a case where the features used for setting the hue scale are the feature "a" and the feature "c", the variation calculation unit 335 obtains variations in the feature "a" and the feature "c", respectively. As the variation, there may be exemplified a variance, a difference between the maximum value and the minimum value of the feature, and the like.

[0097] The feature selection unit 336 selects features as a display target by comparing the variations of the two features for which variations have been obtained. Specifically, in a case where the features used for setting the hue scale are the feature "a" and the feature "c", the feature selection unit 336 compares the variation of the feature "a" with that of the feature "c" and selects the feature having a larger variation as the feature of the display target. For example, in a case where the variation of the feature "c" is larger than the variation of the feature "a", the feature selection unit 336 sets the feature "c" as the feature of the display target and sets the hue scale on the basis of the feature "a". In addition, although it has been described that the feature having the larger variation is selected as a display target, the feature having the smaller variation may be selected, and it is preferable to select a feature that can be clearly displayed.

[0098] The display specification setting unit 334 sets the display scale of the feature selected by the feature selection unit 336 on the basis of the feature with a large variation.

[0099] According to the second embodiment of the present invention described above, the feature selection unit 336 selects the feature of the display target on the basis of the variation calculated by the variation calculation unit 335, and the display specification setting unit 334 selects the display specification of the feature of the display target on the basis of the feature different from the selected feature (the feature of the display target), so that it is possible to select the feature more clearly expressing the difference and display the feature on the display device 4.

(Third Embodiment)

[0100] FIG. 15 is a block diagram illustrating a configuration of an ultrasound observation system 1b including an ultrasound observation apparatus 3b according to a third embodiment of the present invention. The ultrasound observation system 1b illustrated in the figure is configured to include an ultrasound observation apparatus 3b instead of the ultrasound observation apparatus 3 of the ultrasound observation system 1 according to the above-described first embodiment. In the above-described first embodiment, it has been described that the display specification setting unit 334 sets the hue scale according to the values of the features "a" and "c" calculated on the basis of the frequency spectrum. However, in the third embodiment, the hue scale indicating the sound velocity is set according to the value of the hardness.

[0101] An arithmetic unit 33b in the ultrasound observation apparatus 3b is configured to include a feature calculation unit 337 instead of the amplification correction unit 331, the frequency analysis unit 332, and the feature calculation unit 333 of the arithmetic unit 33 described above. The feature calculation unit 337 calculates the sound velocity and the hardness at each position on the basis of the RF data generated by the transmission/reception unit 31. The feature calculation unit 337 obtains the sound velocity by calculating the time until the ultrasound transmitted from the ultrasound transducer 21 is reflected by the observation target and returns on the basis of the RF data. In addition, the feature calculation unit 337 obtains the hardness by calculating the amount of change per unit time on the basis of the plurality of RF data at each position.

[0102] The display specification setting unit 334 according to the third embodiment sets the hue scale which is the display specification of the sound velocity as the feature on the basis of the hardness which is a feature different from the hue scale. FIG. 16 is a diagram illustrating a process executed by the display specification setting unit 334 of the ultrasound observation apparatus 3b according to the third embodiment of the present invention. In FIG. 16, the horizontal axis represents the sound velocity (cm/s). In addition, in FIG. 16, the vertical axis represents the hardness (kPa). FIG. 16 is a graph illustrating the distribution of sound velocity and hardness.

[0103] Herein, as illustrated in FIG. 16, the distribution of sound velocity and hardness differs depending on the type of the characterization of the living tissue (hereinafter, referred to as tissue characterization). For example, a certain tissue characterization is distributed in region Q_3, and other tissue characterization is distributed in region Q_4. At this time, if the sound velocity is expressed with the same hue scale, one tissue characterization is clearly expressed according to the value of the sound velocity, but the difference in the value of the sound velocity may not be clearly expressed in the other tissue characterization. In addition, the value of the sound velocity is distributed in a region deviated from the hue scale, and thus, the sound velocity may not be displayed.

[0104] In the third embodiment, the display specification setting unit 334 sets the display specification of the sound velocity of the display target on the basis of the hardness. Specifically, the display specification setting unit 334 obtains an average value of the plurality of hardnesses calculated by the feature calculation unit 337, compares the average value with a threshold value H_{th}, and sets the hue scale on the basis of the comparison result. For example, in a case where the average value of the hardness is smaller than the threshold value H_{th}, the display specification setting unit 334 sets the hue scale CB_7 according to the range of the sound velocity in the region Q_3 by referring to the display specification information storage unit 371. On the other hand, in a case where the average value of the hardness is equal to or larger than the threshold value H_{th}, the display specification setting unit 334 sets the hue scale CB_8 according to the range of the sound velocity in the region Q_4 by referring to the display specification information storage unit 371. In this manner, by setting the hue scale of the sound velocity on the basis of the hardness, it is possible to set the hue scale corresponding to the tissue characterization according to the distribution of sound velocity and hardness.

[0105] According to the third embodiment of the present invention described above, the display specification setting unit 334 sets the display specification of the feature (hardness) of the display target on the basis of the feature (hardness) different from the feature (sound velocity) of the display target to be displayed on the display device 4, so that it is possible to clearly express the difference of the feature by selecting the optimum hue scale from the distribution of the two features.

[0106] Heretofore, although the modes for carrying out the present invention have been described, the present invention is not be limited only by the embodiments described above. In the first to third embodiments described above, it has been described that the hue scale of one feature of the two features is set on the basis of another feature of the two features, but the present invention is not limited thereto. For example, three features may be used, each feature may be represented by the three orthogonal axes in a coordinate system, and the hue scale of the feature of the display target may be set on the basis of the other two features among the three features. In this case, the threshold value is spatially set by the other two features. In addition, the frequency feature, the sound velocity and the hardness may be set, or the attenuation amount may be used as the feature. In the embodiment, the hue scale is set by using at least two features of the features "a", "b", and "c", which are frequency features, the sound velocity, the hardness, and the attenuation amount.

[0107] In addition, the first to third embodiments described above, two hue scales are set according to a distribution of tissue characterization, but the present invention is not limited thereto. If there are three or more distributions (regions) corresponding to tissue characterization, the hue scales that can be set are also stored in the display specification information storage unit 371 according to the number of the hue scales. In addition, if the change rates of the hues are the same on the plurality of hue scales of the setting target and the central values (average value, median value, mode value) of each region of the plurality of tissue characterization are on a straight line, the colorization range may be set by sliding according to the threshold value.

[0108] In addition, in the first to third embodiments described above, the hue scale is set according to a certain threshold value, but it is also possible to set the range of the feature according to the distribution of the tissue characterization and to set the hue scale by determine in which range the value of the feature different from the display target may be included.

[0109] As described above, the present invention may include various embodiments within the scope without deviating from the technical idea described in the claims.

Industrial Applicability

[0110] As described above, an ultrasound observation apparatus, an operation method of an ultrasound observation apparatus, and an operation program for an ultrasound observation apparatus according to the present invention are useful for clearly expressing a difference in feature. Reference Signs List

[0111]

1, 1a, 1b	ULTRASOUND OBSERVATION SYSTEM
2	ULTRASOUND ENDOSCOPE
3, 3a, 3b	ULTRASOUND OBSERVATION APPARATUS
4	DISPLAY DEVICE
21	ULTRASOUND TRANSDUCER
31	TRANSMISSION/RECEPTION UNIT
32	SIGNAL PROCESSING UNIT
33, 33a, 33b	ARITHMETIC UNIT
34	IMAGE PROCESSING UNIT
35	INPUT UNIT
36	CONTROL UNIT
37	STORAGE UNIT
201	FEATURE IMAGE
202	SUPERIMPOSED IMAGE DISPLAY PORTION
203	INFORMATION DISPLAY PORTION
331	AMPLIFICATION CORRECTION UNIT
332	FREQUENCY ANALYSIS UNIT
333, 337	FEATURE CALCULATION UNIT
333a	APPROXIMATION UNIT
333b	ATTENUATION CORRECTION UNIT
334	DISPLAY SPECIFICATION SETTING UNIT
335	VARIATION CALCULATION UNIT
336	FEATURE SELECTION UNIT
341	B-MODE IMAGE DATA GENERATION UNIT
342	FEATURE IMAGE DATA GENERATION UNIT
371	DISPLAY SPECIFICATION INFORMATION STORAGE UNIT
C_1	FREQUENCY SPECTRUM

Claims

1. An ultrasound observation apparatus for generating an ultrasound image based on an ultrasound signal acquired by an ultrasound probe, the ultrasound probe including an ultrasound transducer configured to transmit ultrasound to an observation target and receive the ultrasound reflected from the observation target, comprising:

   a feature calculation unit configured to calculate a plurality of features based on the ultrasound signal;
   a feature image data generation unit configured to generate feature image data in which a feature of a display target to be displayed together with the ultrasound image, among the plurality of features calculated by the

feature calculation unit, are colorized with a predetermined display specification; and
a display specification setting unit configured to set a display specification of the feature of the display target based on other feature other than the feature of the display target.

2. The ultrasound observation apparatus according to claim 1,
wherein the display specification setting unit is configured to set the display specification of the feature of the display target, based on a feature of a target region in an image based on the ultrasound signal which is the other feature.

3. The ultrasound observation apparatus according to claim 1,
wherein the display specification setting unit is configured to set at least one of a colorization range of the feature of the display target and a change rate of hue of the feature of the display target by comparing a representative value of the other feature with a threshold value.

4. The ultrasound observation apparatus according to claim 1, further comprising a frequency analysis unit configured to analyze a frequency of a signal generated based on the ultrasound signal to calculate a plurality of frequency spectra,
wherein the feature calculation unit is configured to calculate a frequency feature based on a frequency spectrum calculated by the frequency analysis unit as one of the plurality of features.

5. The ultrasound observation apparatus according to claim 4,
wherein the feature of the display target is any one of a sound velocity, a hardness, an attenuation amount, and the frequency feature, and
wherein the other feature is at least one feature different from the feature of the display target, among the sound velocity, the hardness, the attenuation amount, and the frequency feature.

6. The ultrasound observation apparatus according to claim 4,
wherein the feature calculation unit is configured to linearly approximate the frequency spectrum calculated by the frequency analysis unit to calculate the frequency feature.

7. The ultrasound observation apparatus according to claim 6,
wherein the frequency feature is at least one of a slope, an intercept and a mid-band fit obtained by approximating the frequency spectrum calculated by the frequency analysis unit.

8. The ultrasound observation apparatus according to claim 1, further comprising:

a variation calculation unit configured to calculate a variation of each of the features; and
a feature selection unit configured to select a feature of the display target based on the variation of each of the features calculated by the variation calculation unit,
wherein the display specification setting unit is configured to set a display specification of the feature of the display target based on other feature other than the feature of the display target selected by the feature selection unit.

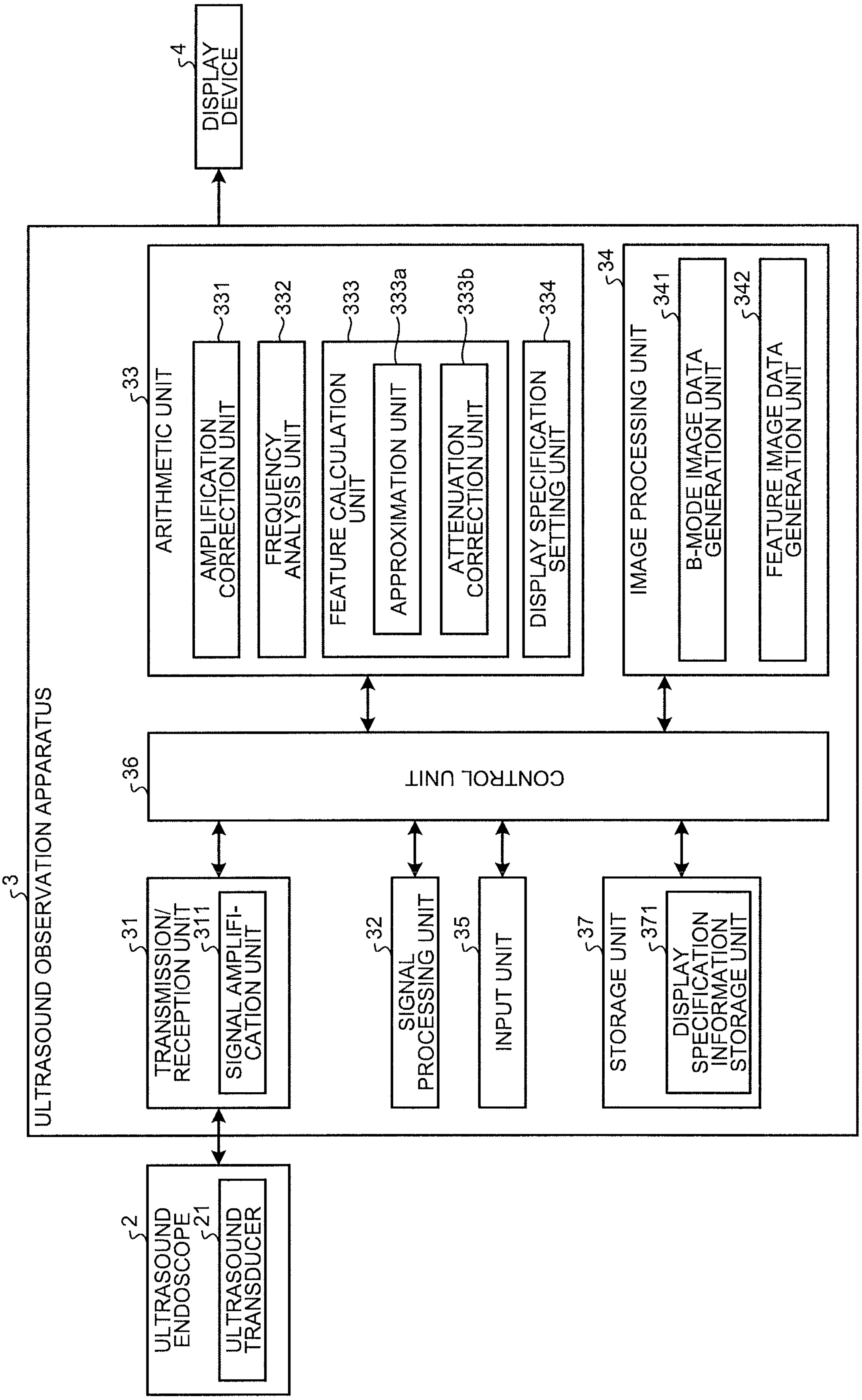
9. A method of operating an ultrasound observation apparatus for generating an ultrasound image based on an ultrasound signal acquired by an ultrasound probe, the ultrasound including an ultrasound transducer configured to transmit ultrasound to an observation target and receive the ultrasound reflected from the observation target, the method comprising:

a feature calculating step of calculating, by a feature calculation unit, a plurality of features based on the ultrasound signal;
a display specification setting step of setting, by a display specification setting unit, a display specification of a feature of a display target to be displayed together with the ultrasound image based on other feature other than the feature of the display target among the plurality of features calculated by the feature calculation unit; and
a feature image data generating step of generating, by a feature image data generation unit, feature image data in which the feature of the display target is colorized with a predetermined display specification.

10. An operation program for an ultrasound observation apparatus for generating an ultrasound image based on an ultrasound signal acquired by an ultrasound probe, the ultrasound including an ultrasound transducer configured to transmit ultrasound to an observation target and receive the ultrasound reflected from the observation target, the operation program causing the ultrasound observation apparatus to execute:

a feature calculation step of calculating, by a feature calculation unit, a plurality of features based on the ultrasound signal;
a display specification setting step of setting, by a display specification setting unit, a display specification of a feature of a display target to be displayed together with the ultrasound image based on other feature other than the feature of the display target among the plurality of features calculated by the feature calculation unit; and
a feature image data generation step of generating, by a feature image data generation unit, feature image data in which the feature of the display target is colorized with a predetermined display specification.

FIG.1


1
ULTRASOUND OBSERVATION APPARATUS
3
ULTRASOUND ENDOSCOPE
2
ULTRASOUND TRANSDUCER
21
TRANSMISSION/ RECEPTION UNIT
31
SIGNAL AMPLIFICATION UNIT
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SIGNAL PROCESSING UNIT
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INPUT UNIT
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STORAGE UNIT
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DISPLAY SPECIFICATION INFORMATION STORAGE UNIT
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CONTROL UNIT
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ARITHMETIC UNIT
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AMPLIFICATION CORRECTION UNIT
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FREQUENCY ANALYSIS UNIT
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FEATURE CALCULATION UNIT
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APPROXIMATION UNIT
333a
ATTENUATION CORRECTION UNIT
333b
DISPLAY SPECIFICATION SETTING UNIT
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IMAGE PROCESSING UNIT
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B-MODE IMAGE DATA GENERATION UNIT
341
FEATURE IMAGE DATA GENERATION UNIT
342
DISPLAY DEVICE
4

FIG.2

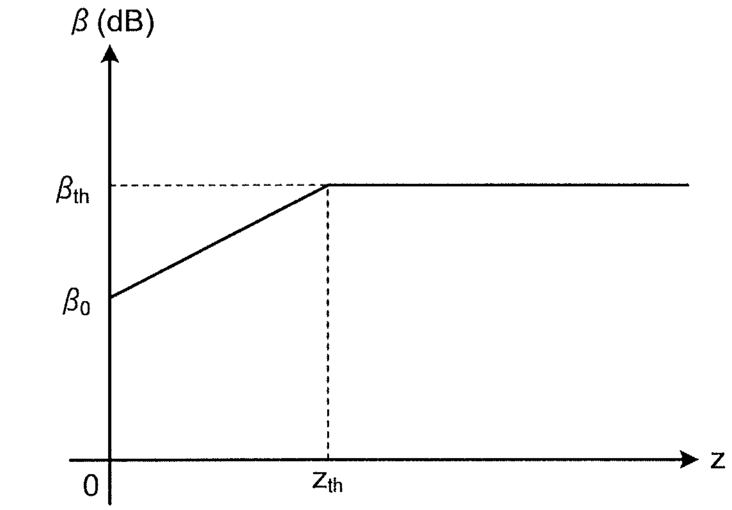


FIG.3

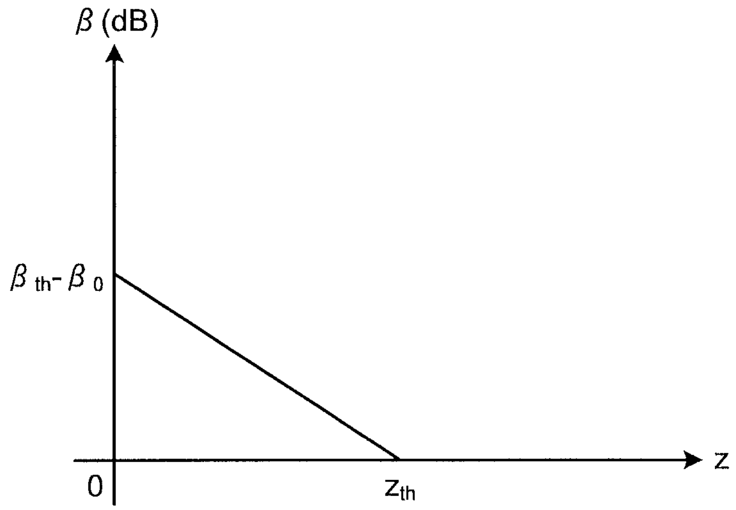


FIG.4

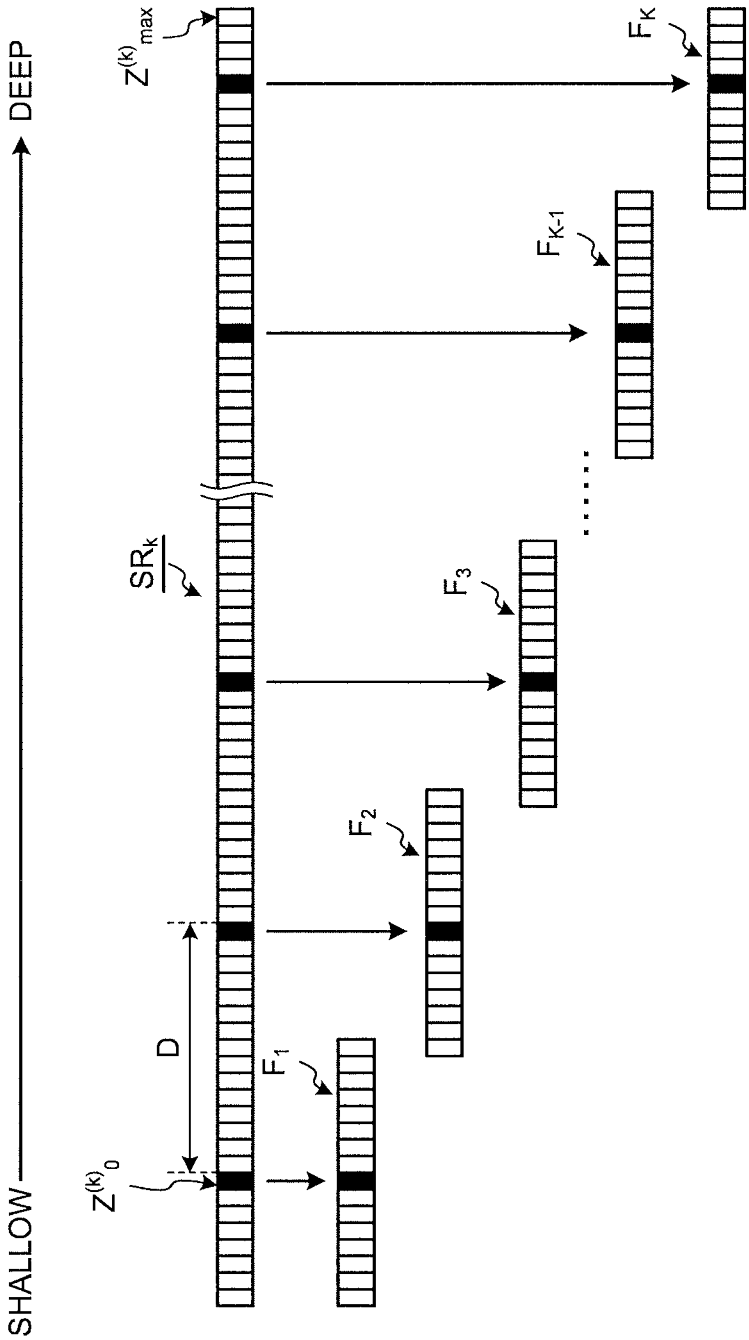


FIG.5

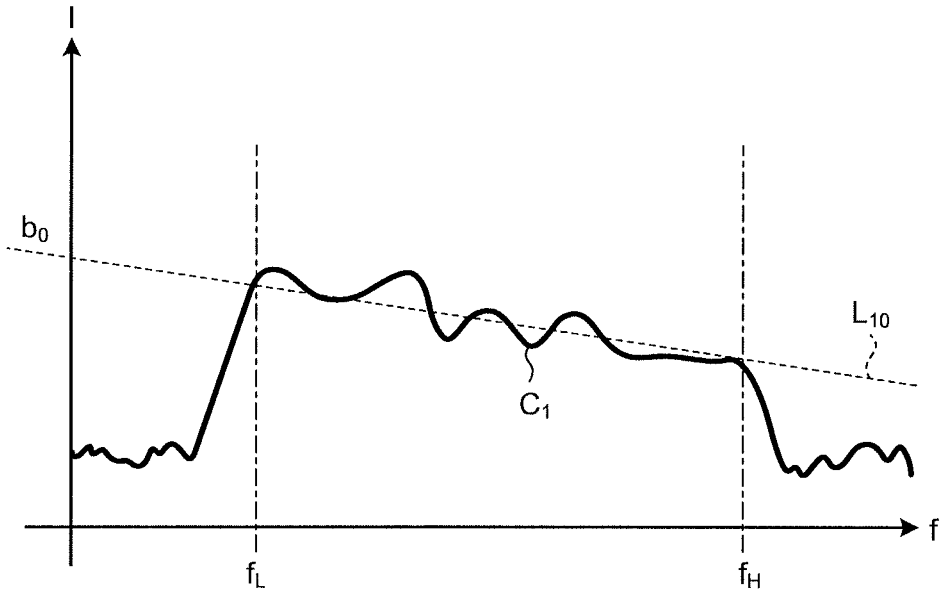


FIG.6

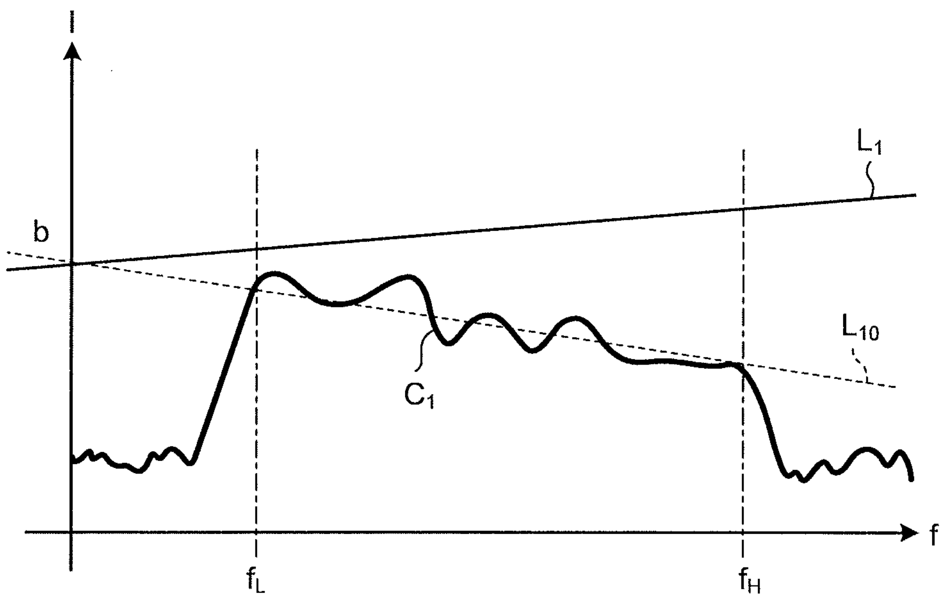


FIG.7

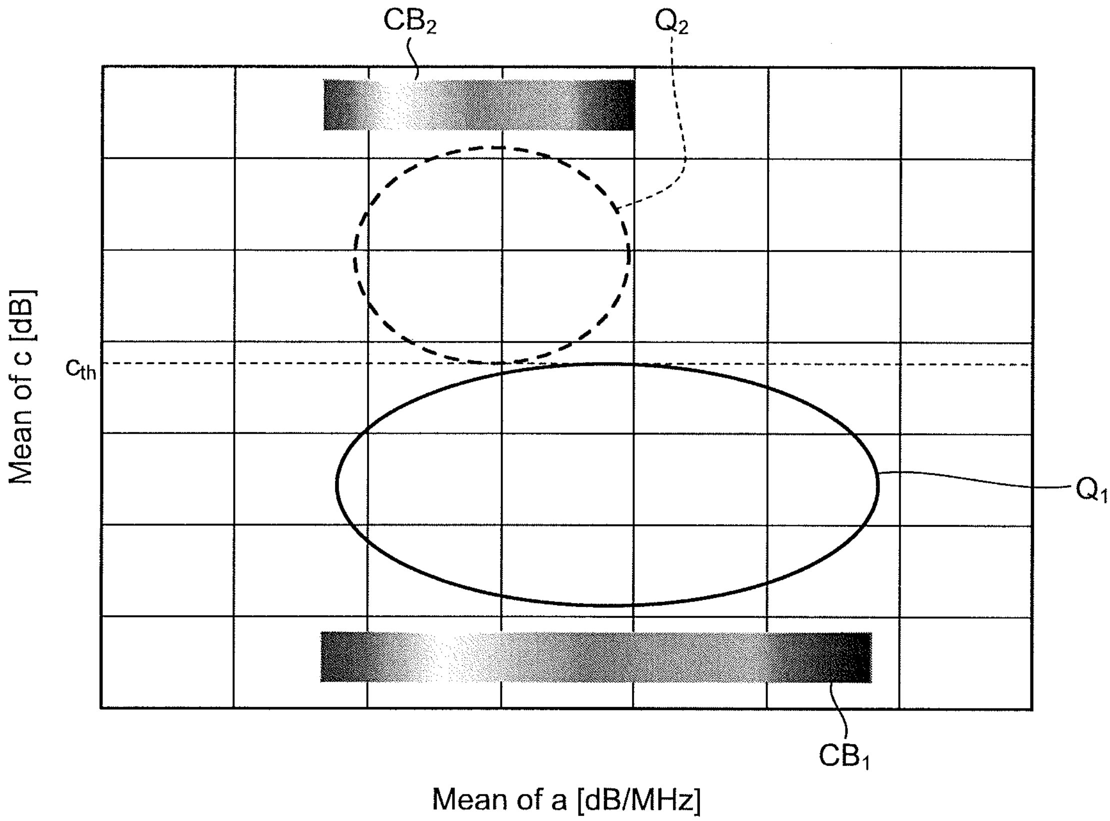


FIG.8

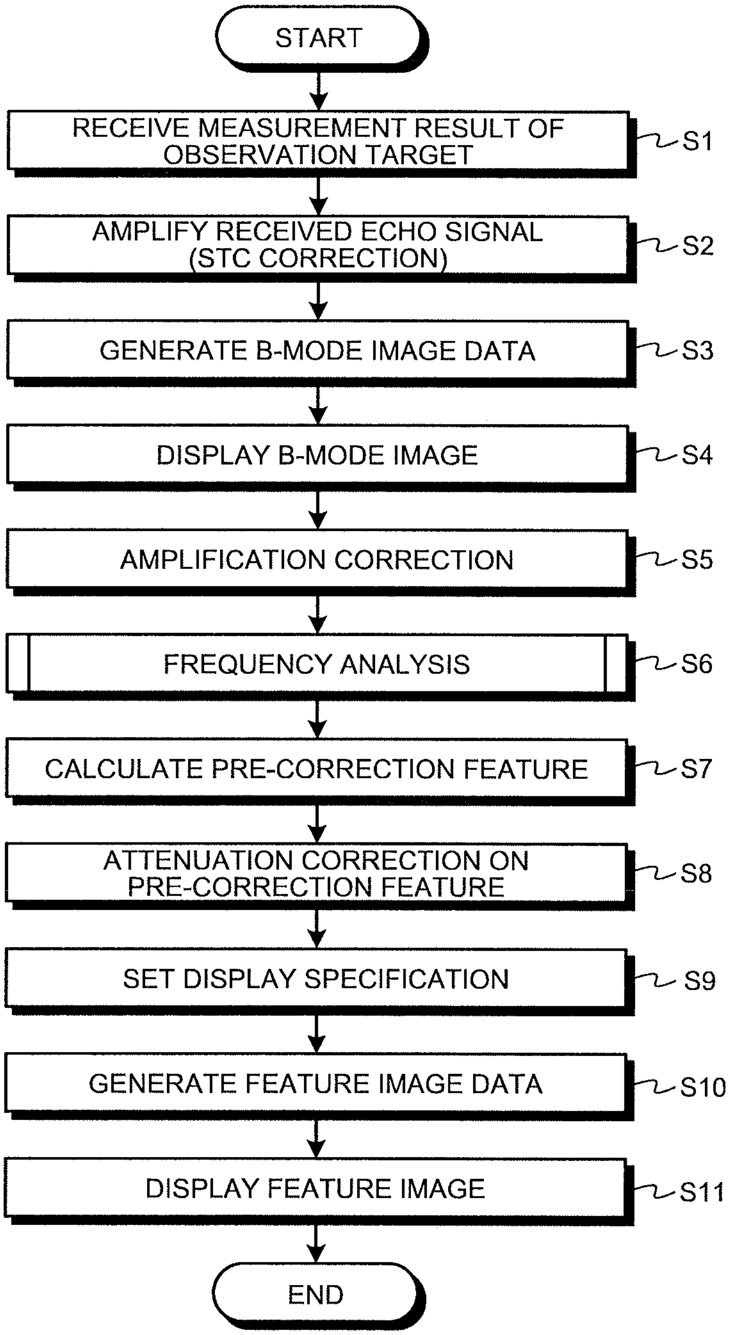

START
RECEIVE MEASUREMENT RESULT OF OBSERVATION TARGET
S1
AMPLIFY RECEIVED ECHO SIGNAL (STC CORRECTION)
S2
GENERATE B-MODE IMAGE DATA
S3
DISPLAY B-MODE IMAGE
S4
AMPLIFICATION CORRECTION
S5
FREQUENCY ANALYSIS
S6
CALCULATE PRE-CORRECTION FEATURE
S7
ATTENUATION CORRECTION ON PRE-CORRECTION FEATURE
S8
SET DISPLAY SPECIFICATION
S9
GENERATE FEATURE IMAGE DATA
S10
DISPLAY FEATURE IMAGE
S11
END

FIG.9

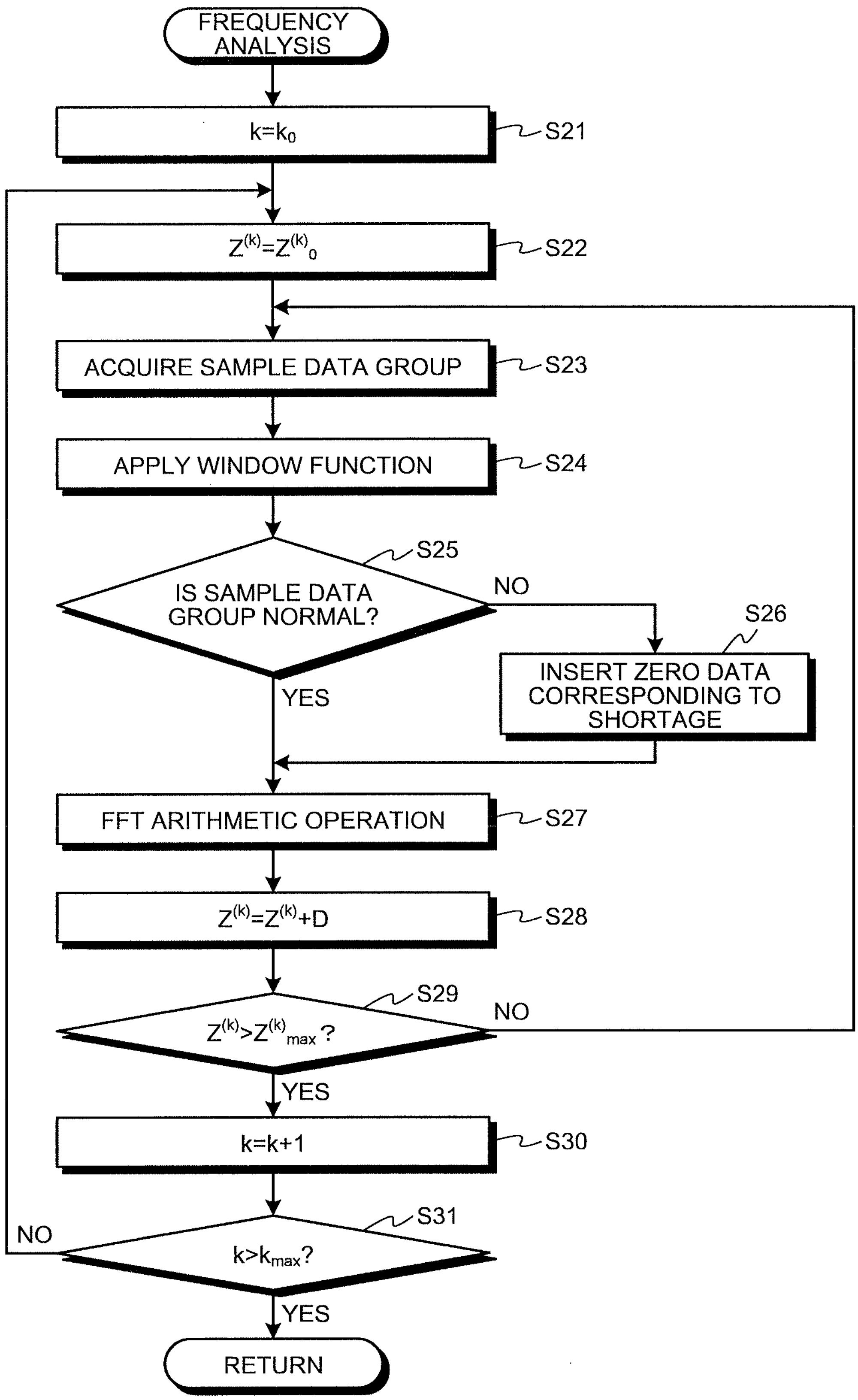

FREQUENCY ANALYSIS
k=k0
S21
Z(k)=Z(k)0
S22
ACQUIRE SAMPLE DATA GROUP
S23
APPLY WINDOW FUNCTION
S24
S25
IS SAMPLE DATA GROUP NORMAL?
NO
S26
INSERT ZERO DATA CORRESPONDING TO SHORTAGE
YES
FFT ARITHMETIC OPERATION
S27
Z(k)=Z(k)+D
S28
S29
NO
Z(k)>Z(k)max ?
YES
k=k+1
S30
S31
NO
k>kmax?
YES
RETURN

FIG.10

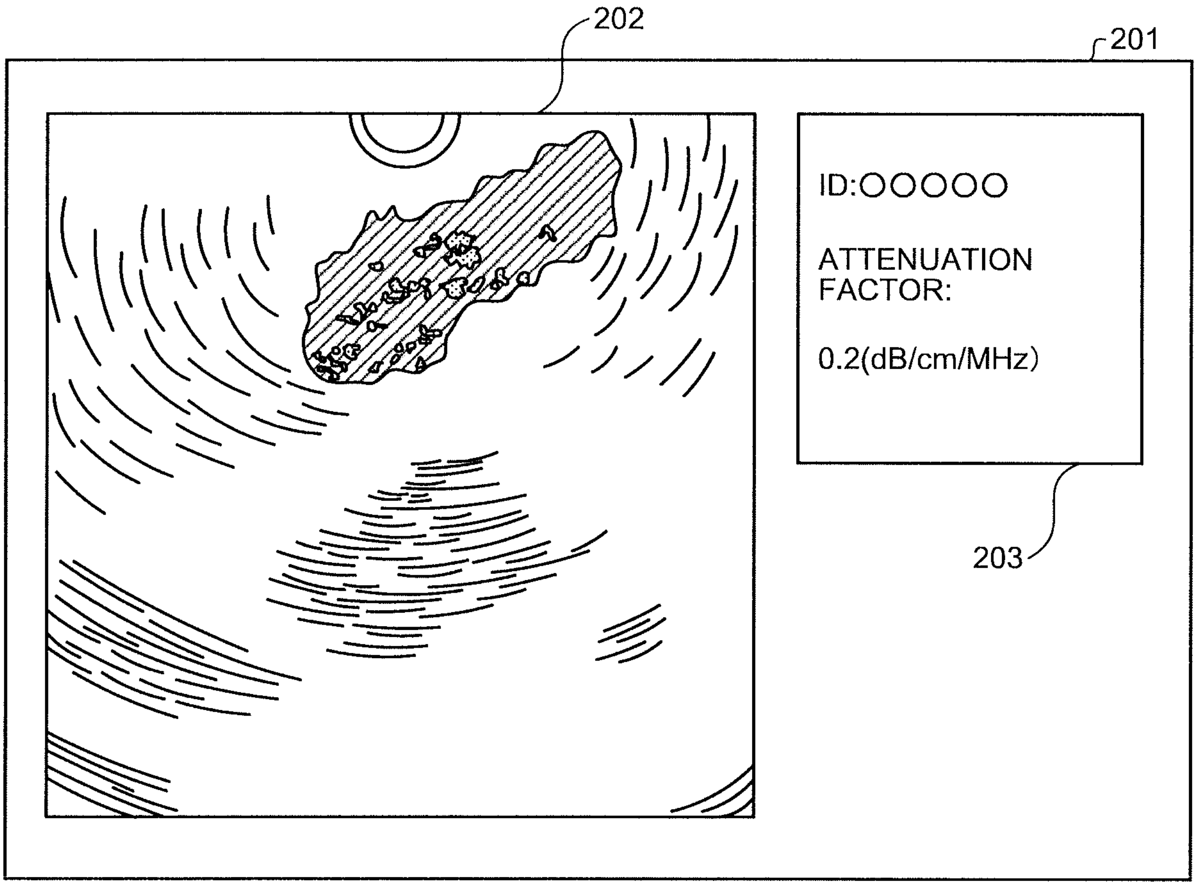


FIG.11

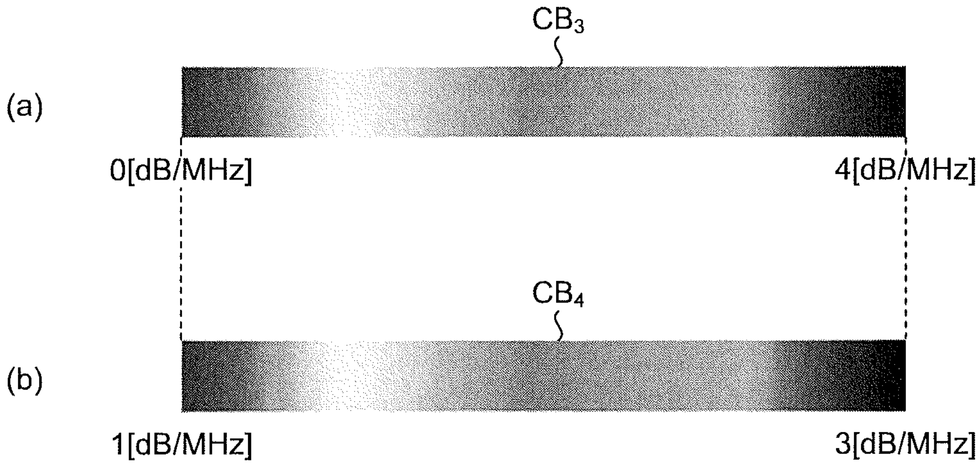

CB3
(a)
0[dB/MHz]
4[dB/MHz]
CB4
(b)
1[dB/MHz]
3[dB/MHz]

FIG.12

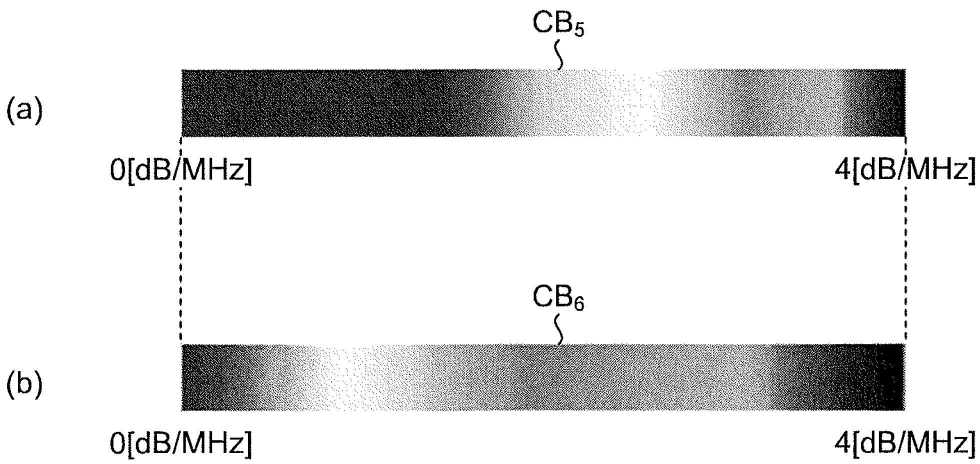

CB5
(a)
0[dB/MHz]
4[dB/MHz]
CB6
(b)
0[dB/MHz]
4[dB/MHz]

FIG.13

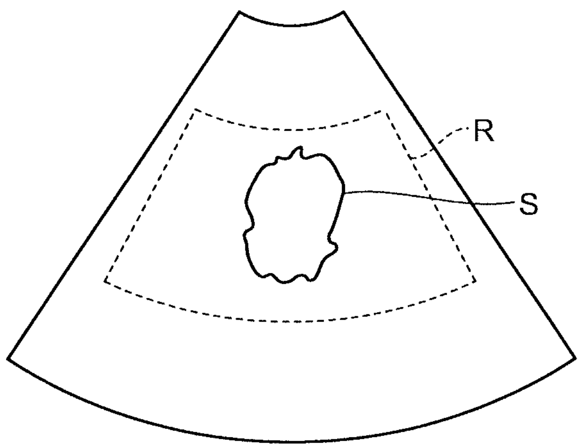


FIG.14

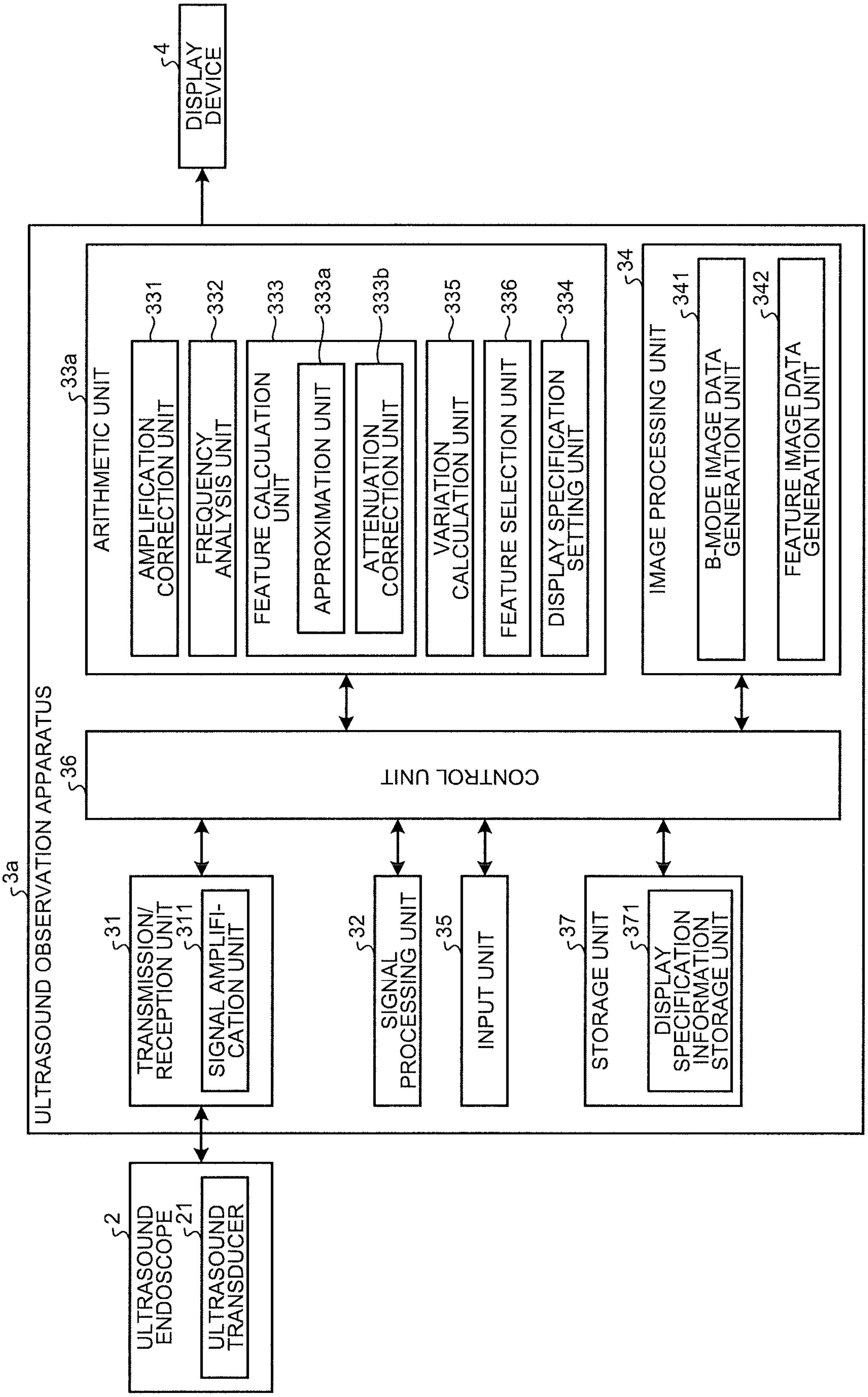
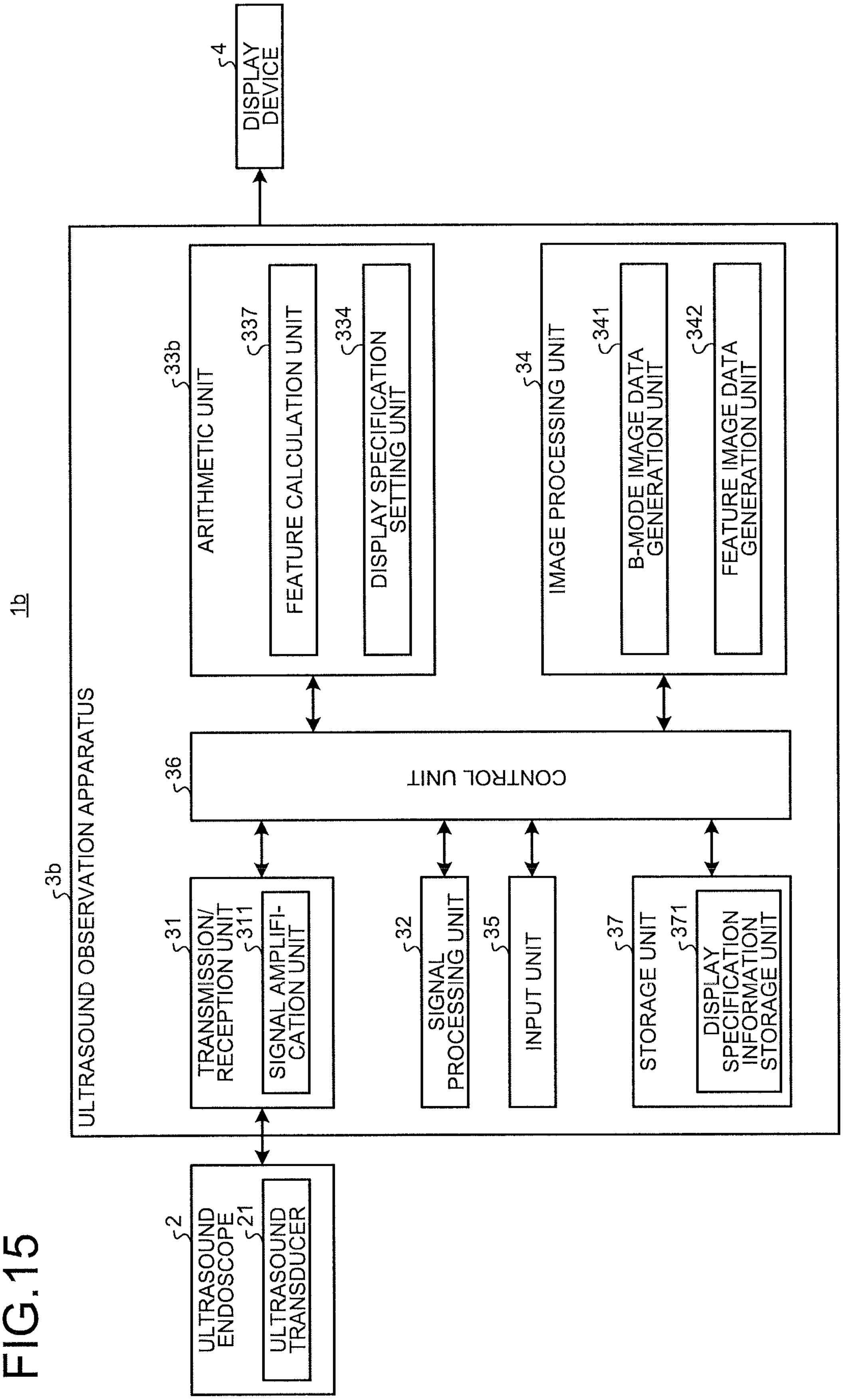

1a
ULTRASOUND ENDOSCOPE
2
ULTRASOUND TRANSDUCER
21
ULTRASOUND OBSERVATION APPARATUS
3a
TRANSMISSION/ RECEPTION UNIT
31
SIGNAL AMPLIFI- CATION UNIT
311
SIGNAL PROCESSING UNIT
32
INPUT UNIT
35
STORAGE UNIT
37
DISPLAY SPECIFICATION INFORMATION STORAGE UNIT
371
CONTROL UNIT
36
ARITHMETIC UNIT
33a
AMPLIFICATION CORRECTION UNIT
331
FREQUENCY ANALYSIS UNIT
332
FEATURE CALCULATION UNIT
333
APPROXIMATION UNIT
333a
ATTENUATION CORRECTION UNIT
333b
VARIATION CALCULATION UNIT
335
FEATURE SELECTION UNIT
336
DISPLAY SPECIFICATION SETTING UNIT
334
IMAGE PROCESSING UNIT
34
B-MODE IMAGE DATA GENERATION UNIT
341
FEATURE IMAGE DATA GENERATION UNIT
342
DISPLAY DEVICE
4

FIG.15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ULTRASOUND TRANSDUCER
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SIGNAL AMPLIFICATION UNIT
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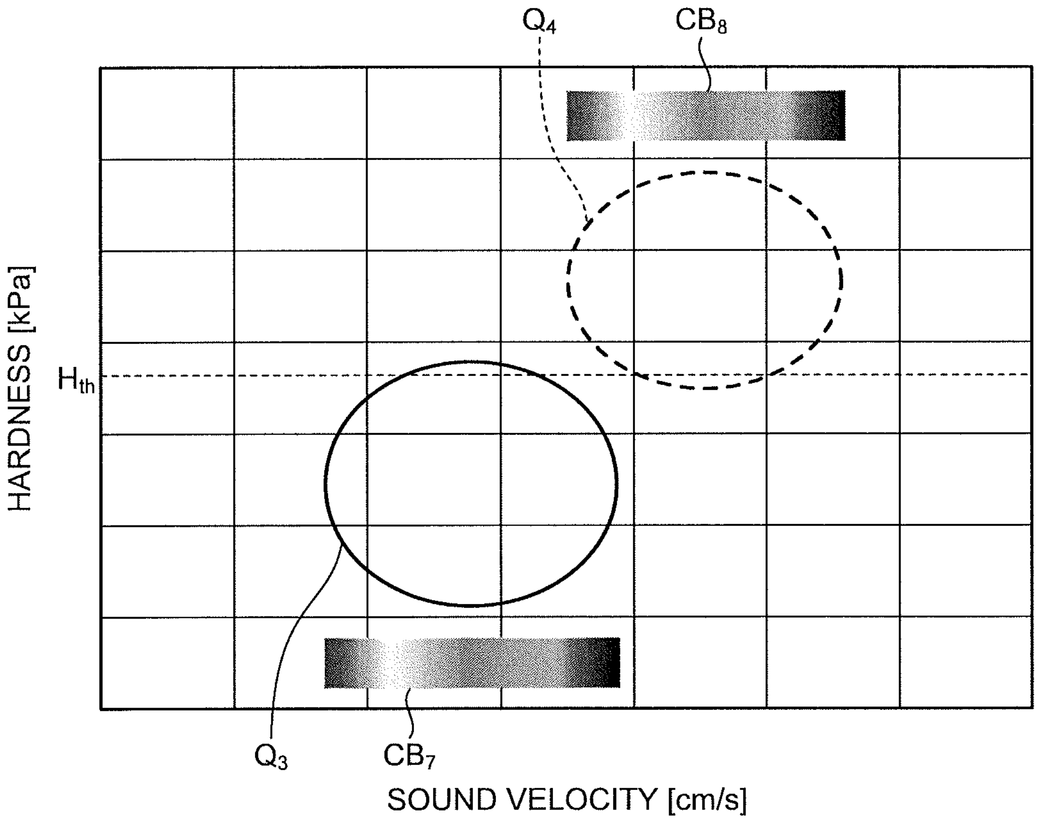
SIGNAL PROCESSING UNIT
32
INPUT UNIT
35
STORAGE UNIT
37
DISPLAY SPECIFICATION INFORMATION STORAGE UNIT
371
CONTROL UNIT
36
ARITHMETIC UNIT
33b
FEATURE CALCULATION UNIT
337
DISPLAY SPECIFICATION SETTING UNIT
334
IMAGE PROCESSING UNIT
34
B-MODE IMAGE DATA GENERATION UNIT
341
FEATURE IMAGE DATA GENERATION UNIT
342
DISPLAY DEVICE
4

FIG.16



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/080607

A. CLASSIFICATION OF SUBJECT MATTER
A61B8/08(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61B8/08

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2016
Kokai Jitsuyo Shinan Koho	1971-2016	Toroku Jitsuyo Shinan Koho	1994-2016

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 4919972 B2 (Hitachi Medical Corp.), 18 April 2012 (18.04.2012), claims 1 to 18; paragraphs [0030] to [0047]; fig. 2 to 5 & US 2010/0220901 A1 paragraphs [0041] to [0069]; claims 1 to 26; fig. 2 to 5 & WO 2007/083745 A1 & EP 1980210 A1 & CN 101370431 A	1,2,8-10 4-7
Y	JP 5079177 B2 (Olympus Medical Systems Corp.), 21 November 2012 (21.11.2012), claims 1 to 16 (Family: none)	4-7

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 November 2016 (28.11.16)	13 December 2016 (13.12.16)
Name and mailing address of the ISA/ Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2016/080607

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2012/011414 A1 (Olympus Medical Systems Corp.), 26 January 2012 (26.01.2012), claims 1 to 11 (Family: none)	4-7
Y	WO 2012/063929 A1 (Olympus Medical Systems Corp.), 18 May 2012 (18.05.2012), claims 1 to 14 & JP 5307939 B2 & US 2013/0030296 A1 claims 1 to 17 & EP 2599441 A1 & CN 103153195 A	4-7

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 5160227 B **[0005]**

专利名称(译)	超声波观察装置，超声波观察装置的操作方法，超声波观察装置的操作程序		
公开(公告)号	EP3366220A1	公开(公告)日	2018-08-29
申请号	EP2016857383	申请日	2016-10-14
[标]申请(专利权)人(译)	奥林巴斯株式会社		
申请(专利权)人(译)	OLYMPUS CORPORATION		
当前申请(专利权)人(译)	OLYMPUS CORPORATION		
[标]发明人	NAKATSUJI TOMOHIRO		
发明人	NAKATSUJI, TOMOHIRO		
IPC分类号	A61B8/08		
CPC分类号	A61B8/08 A61B8/12 A61B8/461 A61B8/485 A61B8/5207 A61B8/5246 A61B8/5269 G01S7/52033 G01S7/52036 G01S7/52042 G01S7/52071 A61B8/48 G06F3/04845		
优先权	2015208648 2015-10-23 JP		
其他公开文献	EP3366220A4		
外部链接	Espacenet		

摘要(译)

根据本发明的超声波观测设备包括：特征计算单元，其基于超声信号计算多个特征;特征图像数据生成单元，生成特征图像数据，在该特征图像数据中，与特征计算单元计算出的多个特征中的视觉信息相关联地，以预定的显示规格对要与超声图像一起显示的显示对象的特征进行着色。显示器规格设置单元，基于除显示器目标的特征之外的其他特征来设置显示器目标的特征的显示器规格。

FIG.1