PATENT SPECIFICATION (11) 1 577 976

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(21) Application No. 27518/77 (22) Filed 30 Jun. 1977

(31) Convention Application No. 2629942 (32) Filed 2 Jul. 1976 in

(33) Fed. Rep. of Germany (DE)

(44) Complete Specification Published 29 Oct. 1980

(51) INT.CL.[3] G01N 29/04 //
A61B 10/00

(52) Index at Acceptance
G1G 1A 3C 3R 4A4 7T EA

(19)

(54) SCANNING APPARATUS

(71) We, SIEMENS AKTIENGESELLSCHAFT, a Germany company of Berlin and Munich, Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

This invention relates to scanning apparatus. One aspect of the invention relates to an ultrasonic video apparatus operating on the pulse-echo principle, for example for medical diagnosis, with ultrasonic applicator for linear ultrasonic scanning of an examination subject and image display device with line generator for producing the echo pulses on display lines, as well as an image generator for displacement of the lines as a function of the displacement of the ultrasonic beam in the subject.

In apparatus of this type the problem is to obtain high image frequencies in the image reproduction simultaneously with the highest possible number of scanning lines in the ultrasonic echo image. Where resolution of the echo image is good a virtually flicker-free image is then also produced due to the relatively high image frequency.

According to the invention there is provided ultrasonic video apparatus operating on the pulse-echo principle including an ultrasonic applicator for linear ultrasonic scanning of an examination subject, and an image generator for displacing the display lines as a function of the displacement of the ultrasonic beam in the subject, and the apparatus being designed to scan a section of the subject along a number of equally spaced scanning lines; characterized in that, the ultrasonic applicator is constructed for the linear ultrasonic scanning of the examination subject simultaneously along several scanning lines, these lines lying at specific distances from one another that are constant for all successive scans and the distance between adjacent simultaneous scan lines being multiple of the adjacent line spacing of said number of scan lines, and in that the apparatus includes buffer storage means and control means such that in operation the echo signals of all the simultaneously scanned lines are stored in parallel and then read out sequentially within the duration of the transmitting/receving cycle for a subsequent simultaneous line scan, and display on lines on the image display device with image display line spacing and positions corresponding to the ultrasonic line scan spacing and positions in the subject.

In such apparatus with an unchanged normal basic clock pulse rhythm of the transmitting/receiving cycles, increased line scanning frequency is produced only as a result of simultaneously occurring multiple scanning, and thus increased image frequency is also produced where the read-out time of all the echo pulses of the scanning lines of one scanning line formation is compressed into the receiving time of a single transmitting/receiving cycle. Thus where the number of lines is relatively high the image frequency of the ultrasonic image representation is correspondingly increased with the simplest means.

The invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 shows a circuit diagram of ultrasonic video apparatus in accordance with an example of the invention,

Figure 2 shows signal waveforms produced during an ultrasonic scanning process using the apparatus shown in Figure 1, and

Figure 3 shows a diagram representing the line and associated image sweep voltage waveforms on an image display device for building-up an ultrasonic echo image.

Referring to Figure 1, an ultrasonic applicator 1 is constructed as an ultrasonic array comprising a plurality of ultrasonic trans-

ducers W_1 to W_n (piezoelectric crystal plates), which are fixed in a row on a bearing member 2. This member 2 is made of a material which effectively damps ultrasonic waves. The transducers W_1 to W_n can be selectively energised, either individually or in groups, by means of high frequency pulses produced by a high frequency pulse generator 3 such that they radiate ultrasonic pulses into a section of an examination subject 5, for example a human body, in the direction indicated by arrows 4. The direction of the transducers W_1 to W_n into individual or group formation is effected by means of a control device which comprises two control shift registers 6 and 7 and control switches S_1 to S_n, the shift registers forming switching clock pulse generators for the switches S_1 to S_n. This control device connects the transducers to be energised with the high frequency pulse generator 3 in the transmitting cycle, or with two echo pulse receiving amplifiers 8 and 9 in the receiving cycle. The apparatus shown in Figure 1 operates preferably with ultrasonic scanning by two simultaneous scanning lines. To achieve this, the bank of control switches S_1 to S_n is subdivided into two switches groups, the first of which comprises the switches S_1 to $S_{n/2}$ for controlling the transducers W_1 to $W_{n/2}$, specifically from the first transducer array half, and the second transducer array half. The switches of each switch group are activated simultaneously and jointly by the high frequency pulses produced by the high frequency pulse generator 3 during the transmitting cycle. Control of echo pulse reception is effected separately for each switch group by means of the associated shift register 6 or 7 or the associated echo pulse receiving amplifier 8 or 9, respectively. Echo signals are always received from two simultaneous ultrasonic scanning lines chronologically stepped along the array (as explained below) and are displayed on image lines by an electron beam tube 10, with which there is associated, in the normal manner, a line sweep generator 11 for supplying a horizontal deflection coil 12, and an image (field) sweep generator 13 for supplying a vertical deflection coil 14 of the electron beam tube 10. The electron beam tube 10 further comprises an intensity modulator 15 for intensity modulation of the image lines at the frequency of the echo pulses being received. The reading-in and reading-out of the echo signals associated with each line pair are effected according to an alternating buffer storage operation such that echo signals associated with two successive line pairs are read-in alternately to each of two buffer storage circuit pairs 16, 17 and 18, 19, and are similarly read-out alternately from these storage circuit pairs. The reading-in time for the parallel reading-in of echo pulses associated with one line pair into a buffer storage circuit pair 16, 17 or 18, 19 substantially corresponds to the receiving time of these echo pulses from the examination subject 5. The successive sequential reading-out of stored information from each buffer storage circuit pair, on the other hand, occurs at a high frequency, preferably corresponding to half the duration of the reading-in time. Reading-in and reading-out of echo signal information in respective storage circuit pairs 16, 17 and 18, 19 are effected at the frequency of oscillation of switches 20, 21 at the input, and the frequency of oscillation of switches 22, 23, 24 at the output of these storage circuit pairs. The switches 20, 21 at the input and the switches 22, 23 at the output of the buffer storage circuit pairs 16, 17 and 18, 19 oscillate at the same frequency, but in counter clock pulse operation. The output switch 24, on the other hand, oscillates at twice the switch-over frequency of the switches 20 to 23.

To set the switch-over frequency for the switch 24 there is provided a basic clock pulse generator 25 which is synchronized with the image sweep generator 13. A control clock pulse generator 26 is provided for setting the counter clock pulse change-over frequency for the switch pairs 20, 21 and 22, 23 and also for setting the frequency for the transmitting/receiving cycles of the ultrasonic applicator 1 and the trigger clock pulses for producing line sweep and image sweep pulses. This control clock pulse generator 26 is here, in its preferable form, a 2:1-scaling member, whoch scales the basic clock pulse frequency T_G produced by the basic clock pulse generator 25 by half to give the frequency $T_L = T_{G/2}$.

The function of the apparatus shown in Figure 1 will now be described with reference to Figures 2 and 3.

The switch 24 shown in Figure 1 oscillates at the frequency of the basic clock pulses T_G produced by the basic clock pulse generator 25. Alternate switching-over of the input switches 20 and 21 of the storage pairs 16, 17 and 18, 19 occurs in counter rhythm to that of the output switches 22, 23 at the frequency of the control clock T_L produced by the control clock pulse generator 26. The control clock pulses T_L also simultaneously effect successive clock-pulsing of the register positions of the shift registers 6 and 7. As a result, one or more switches of the first switch group S_1 to $S_{n/2}$ together with one or more corresponding switches of the second switch group $S_{n/2+1}$ to S_n are closed simultaneously at the frequency of the clock pulsing in each case. Since the high frequency pulse generator 3 always produces a high frequency pulse on the occurrence of a

control clock pulse T_L, associated transducers or transducer groups of the first and second array halves are energised simultaneously by means of the simultaneously closed switches or switch sub-group pairs such that ultrasonic radiations, and thus ultrasonic scanning, is effected simultaneously by two scanning lines. The echo pulses resulting from each of these two simultaneous scanning lines are received in parallel formation for each scanning line by the receivers 8 and 9 and are fed, in alternate rhythm with respect to the next echo line pair, alternately into one or other of the buffer storage circuit pairs 16, 17 or 18, 19. In the apparatus shown in Figure 1 (with individual transducer control) for example, the reading-in of echo pulses of scanning lines produced by the transducer W_1 into the store 17 is therefore effected, whilst the echo pulses of further scanning lines produced simultaneously by the transducer $W_{n/2+1}$ are read-in to the store 16. In the case of further clock pulsing to the next scanning lines produced by the transducer pair W_2 and $W_{n/2+2}$ on the other hand, reading-in of the echo pulses of these scanning lines into the stores 18 and 19 is effected together with the simultaneous switch-over of the switches 20 and 21 into the switch positions indicated by broken lines in Figure 1. During the period that these echo pulses are being read-in, successive fast scanning of the store contents of the stores 16 and 17 is effected by means of switching the output switches 22 and 23 into the switch positions indicated by broken lines, and also by means of the output switch 24 which is switched over twice as quickly. This process is repeated in alternate rhythm with subsequent scanning line pairs. Echo pulses are thus read-in to the storage pairs 16, 17 and 18, 19 in parallel formation at the frequency of progressive linear scanning of the examination subject 5 by two simultaneous scanning lines and is read-out alternately with doubled clock pulses in chronological succession during the receiving time of the echo pulses of the next two scanning lines. The alternate clock pulses for the read-in and read-out cycles may be seen from Figure 2 with reference to the switching pulse waveforms of the input and output clock pulses T_{E16} to T_{E19} and T_{A16} to T_{A19} respectively of the stores 16 to 19 together with the read-out clock pulses T_{AL1} or T_{AL2} of the output switch 24. The lines of echo pulses associated with individual read-out clock pulses is designated according to the chronological sequence of its occurrence by Z_1, Z_2, Z_3 etc. The echo signal line grid i.e. the grid of lines on which the echo signals lie, to form the pulse echo image representation on the picture screen of the electron beam tube 10, which exactly corresponds to that of the ultrasonic scanning in the examination subject 5, is shown on the left hand side of Figure 3. The spatial distance between the associated scanning and image reproduction lines of one line pair is designated by d, where di is approximately equal to half the width of the screen of the electron beam tube 10, or half the length of the ultrasonic array 1. An image sweep voltage U_{BK}, with which such a line grid can be realised in its simplest form, is represented on the right hand side of Figure 3 as its waveform $U_{BK}(t)$. The period t_B represents the time interval for one sweep deflection of the image sweep across the picture screen of the electron beam tube 10, whilst the period t_{BR} represents the fly-back time of the electron beam to its starting position after the completion of an image sweep.

WHAT WE CLAIM IS:-

1. Ultrasonic video apparatus operating on the pulse-echo principle including an ultrasonic applicator for linear ultrasonic scanning of an examination subject, and an image display device having a line generator for reproducing the echo pulses on display lines corresponding to the linear scans, and an image generator for displacing the display lines as a function of the displacement of the ultrasonic beam in the subject, and the apparatus being designed to scan a section of the subject along a number of equally spaced scanning lines; characterized in that the ultrasonic applicator is constructed for the linear ultrasonic scanning of the examination subject simultaneously along several scanning lines, these lines lying at specific distances from one another that are constant for all successive scans and the distance between adjacent simultaneous scanning lines being a multiple of the adjacent line spacing of said number of scanning lines, and in that the apparatus includes buffer storage means and control means such that in operation the echo signals of all the simultaneously scanned lines are stored in parallel and then read out sequentially within the duration of the transmitting/receiving cycle for a subsequent simultaneous line scan, and displayed on lines on the image display device with image display line spacing and positions corresponding to the ultrasonic line scan spacing and positions in the subject.

2. Ultrasonic video apparatus according to claim 1, characterized in that the buffer memories each with sufficient storage to store all the echo signals of one simultaneous line scan cycle and the control means operates such that reception and read-out of the echo signals of simultaneous line scan combinations are effected by an alternating buffer storage operation in which the echo signals of a simultaneous line combination are read into the other buffer

memory from that used for the immediately preceding line scan combination echo signals whilst these preceding echo signals are being read out from their buffer memory.

3. Ultrasonic video apparatus according to claim 1 or 2, characterized in that the sum of the sequential read-out times for the successive reading-out of all the line information of one line combination corresponds approximately to the read-in time for the parallel reading-in of one line combination into the buffer storage meas.

4. Ultrasonic video apparatus according to any of claims 1 to 3, characterized in that the ultrasonic applicator is constructed to scan two lines simultaneously.

5. Ultrasonic video apparatus according to claim 4, characterized in that the ultrasonic applicator incorporates an ultrasonic array formed by a plurality of adjacently disposed transducer elements, with each of the elements of half of the array being connectable to an excitation source through a respective one of a first group of control switches, and with each of the transducer elements of the other half of the array being connectable to an excitation source through a respective one of a second group of control switches, and in that the arrangement is such that in each of a continuous sequence of cycles there is always one switch or one switch sub group of each switch group closed for the purpose of simultaneous excitement of two transducer elements or transducer element groups to effect said ultrasonic scanning along lines lying at specific distances from one another.

6. Ultrasonic video apparatus according to claim 5, characterized in that the apparatus incorporates a shift register as a switching clock pulse generator connected to each switch group to effect the simultaneous switching of the corresponding switches of the switch groups.

7. Ultrasonic video apparatus according to claim 5 or 6, characterized in that there is a common excitation source, for both switch groups, formed by a single high frequency pulse generator.

8. Ultrasonic video apparatus according to claim 7, characterized in that for each switch group there is a separate echo signal receiver.

9. Ultrasonic video apparatus substantially as herein described with reference to the accompanying drawings.

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Printed for Her Majesty's Stationery Office,
by Croydon Printing Company Limited, Croydon, Surrey, 1980.
Published by The Patent Office, 25 Southampton Buildings,
London, WC2A 1AY, from which copies may be obtained.

1577976 COMPLETE SPECIFICATION
2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 1

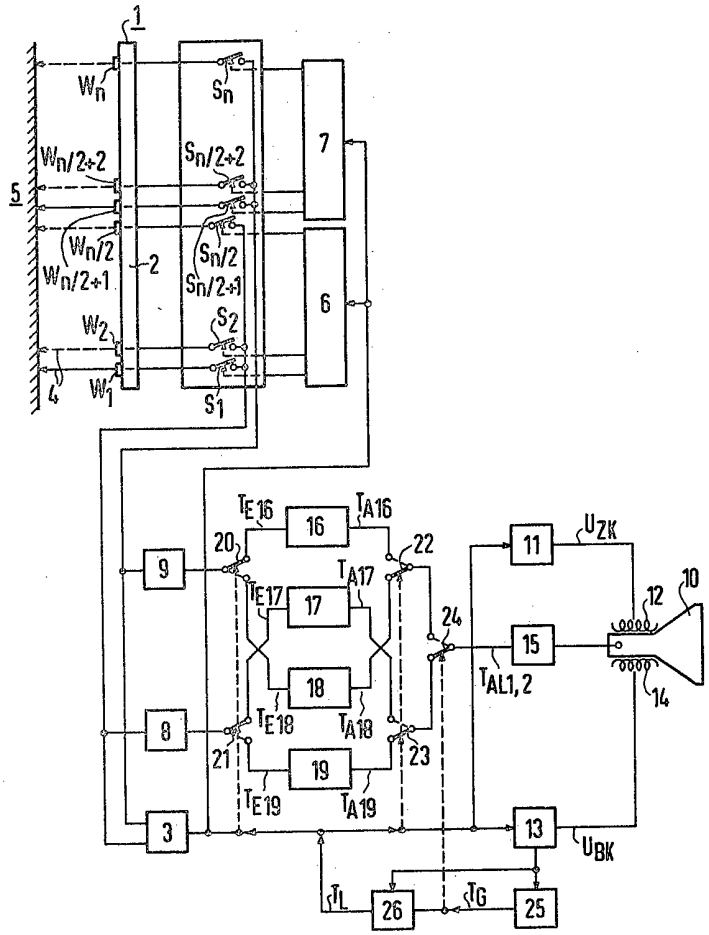

Fig.1

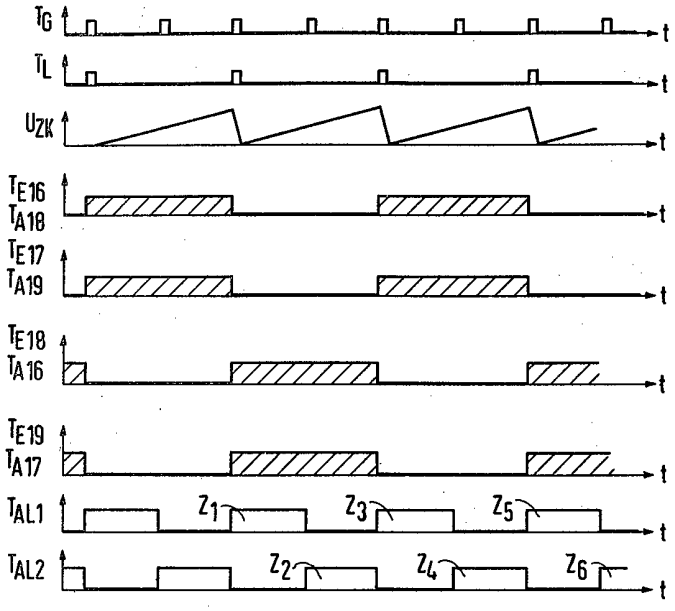
T_G
T_L
U_{ZK}
T_{E16} T_{A18}
T_{E17} T_{A19}
T_{E18} T_{A16}
T_{E19} T_{A17}
T_{AL1}
T_{AL2}
Z_1 Z_3 Z_5
Z_2 Z_4 Z_6
t

Fig.2

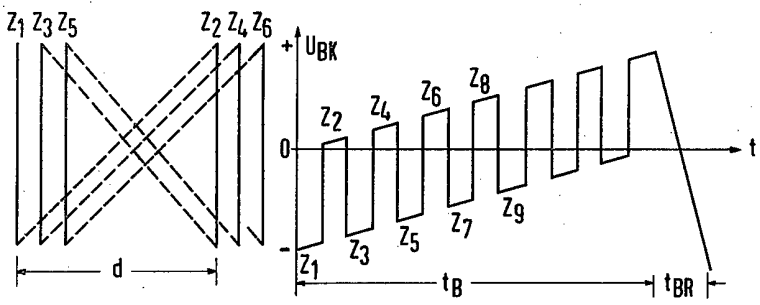
Z_1 Z_3 Z_5
Z_2 Z_4 Z_6
+
U_{BK}
0
-
Z_1 Z_2 Z_3 Z_4 Z_5 Z_6 Z_7 Z_8 Z_9
t
d
t_B
t_{BR}

Fig.3