June 6, 1967 J. D. RICHARD 3,324,451

ECHO RANGING AND RECORDING APPARATUS

Filed June 5, 1964 5 Sheets-Sheet 1

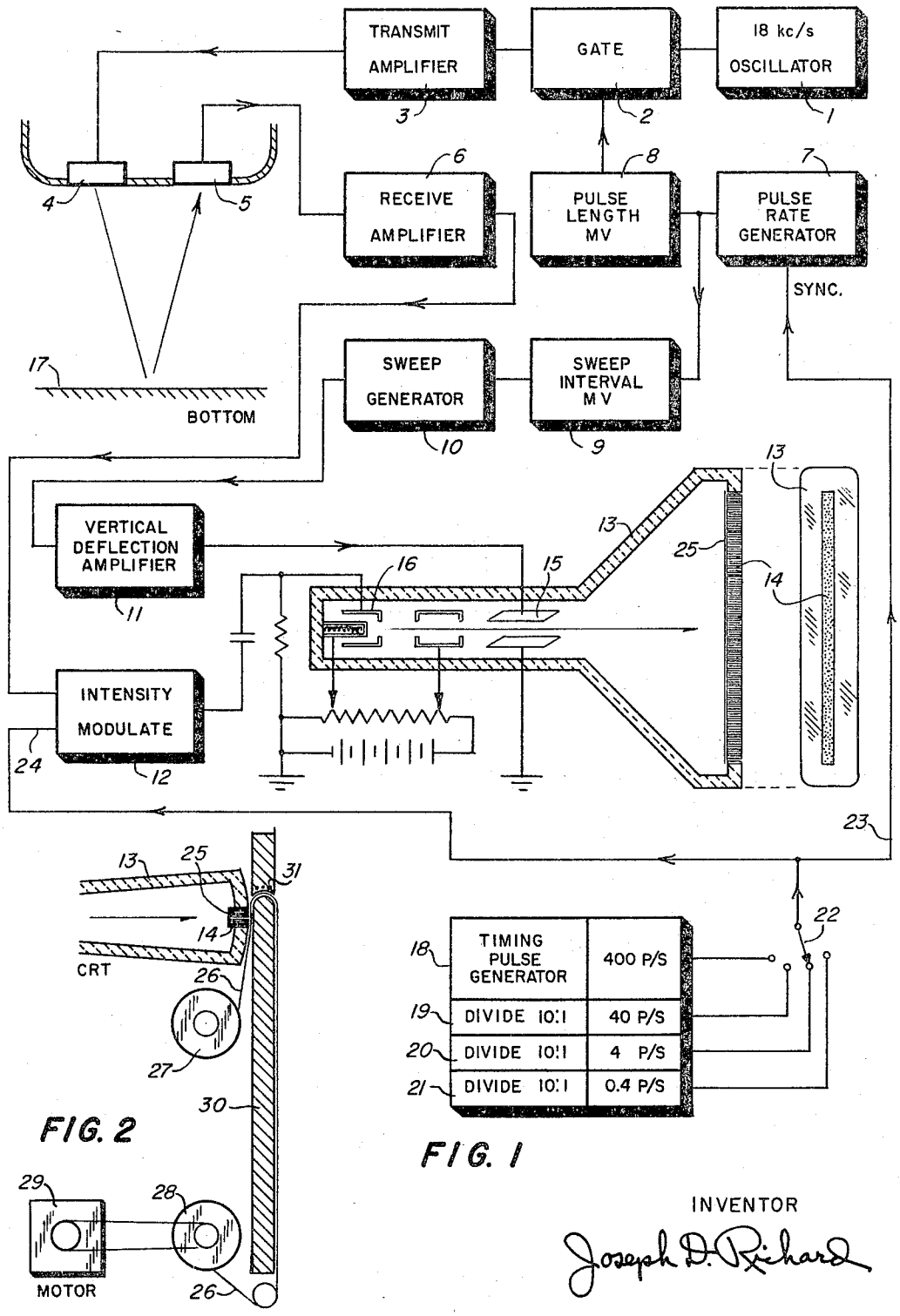

FIG. 2

FIG. 1

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ECHO RANGING AND RECORDING APPARATUS

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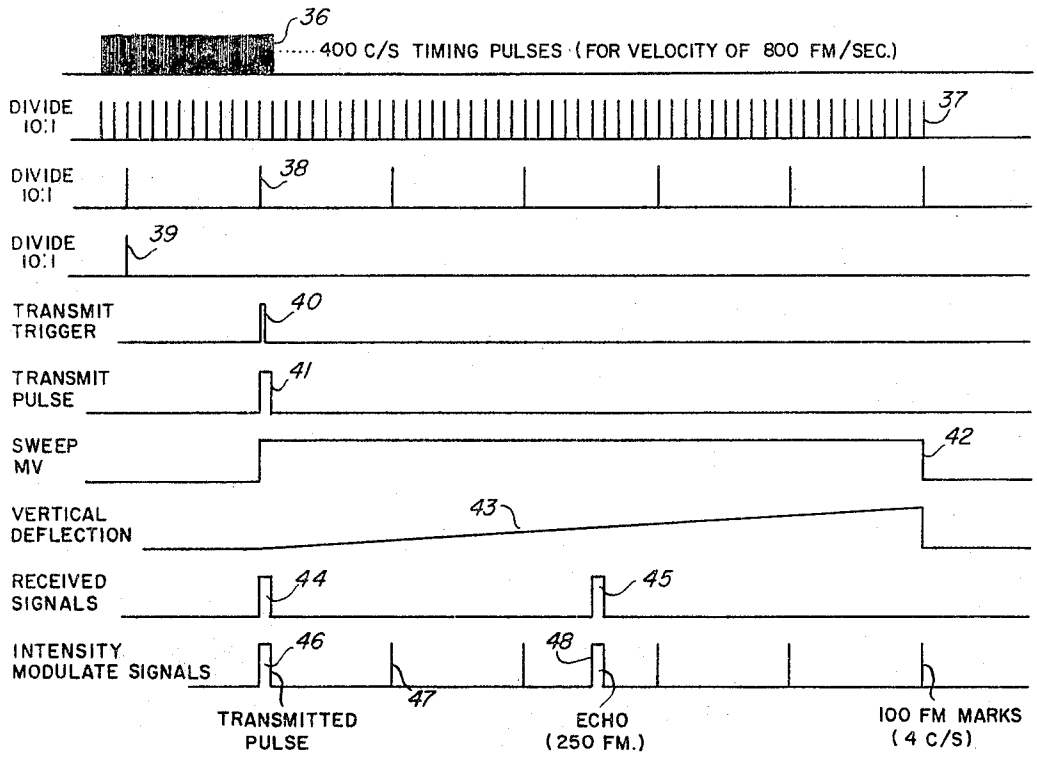

FIG. 3

49 RANGE (FM)	REPETITION RATE	SWEEP INTERVAL	MARKER FREQ.
0-5	10 P/S	.0125 S	400 C/S
0-50	2 P/S	0.125 S	40 C/S
0-500	0.5 P/S	1.25 S	4 C/S
0-5000	.05 P/S	12.5 S	0.4 C/S

FIG. 4

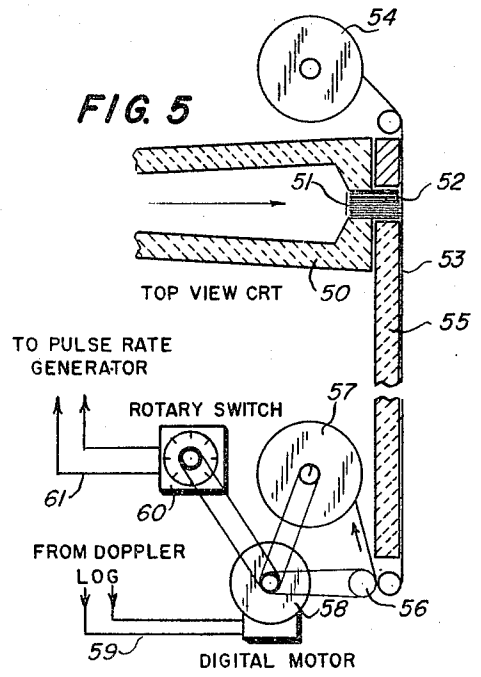

FIG. 5

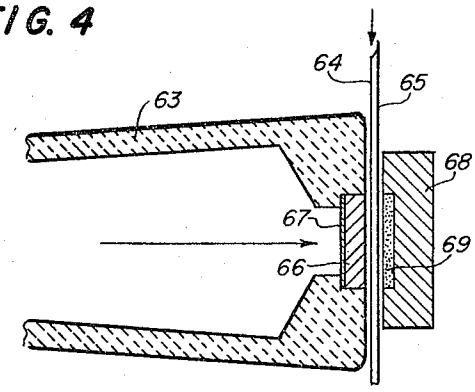

FIG. 6

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ECHO RANGING AND RECORDING APPARATUS

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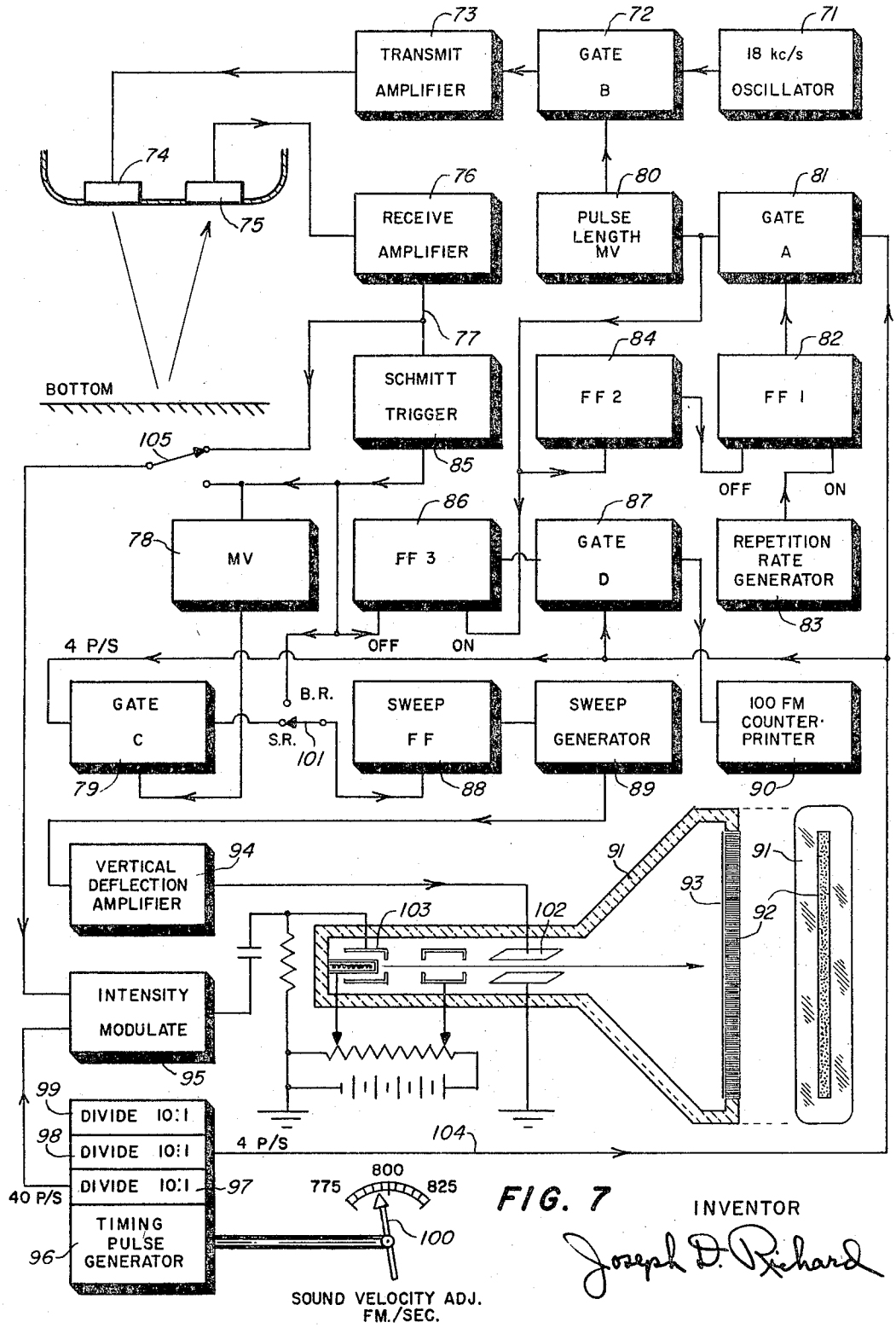

FIG. 7

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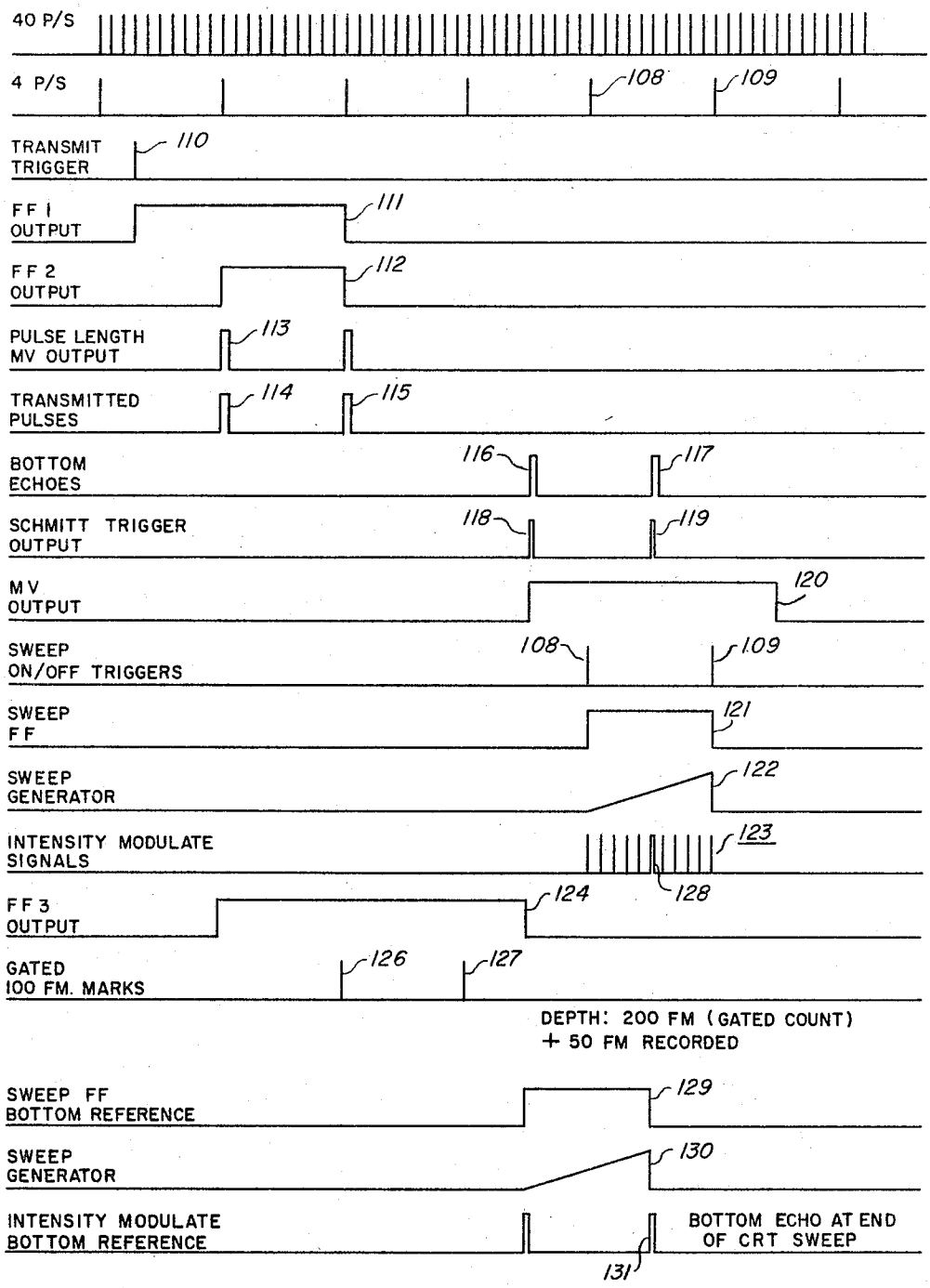

FIG. 8

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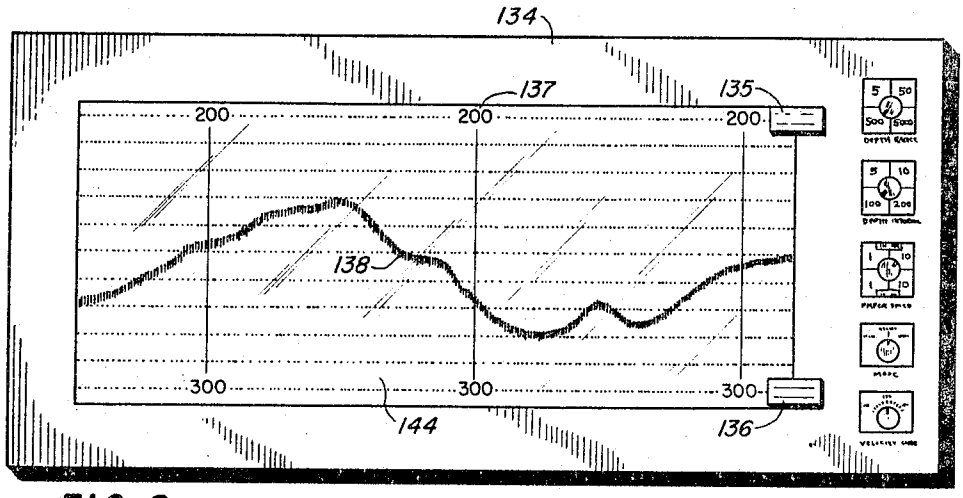
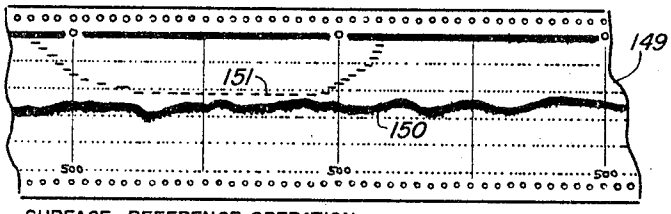
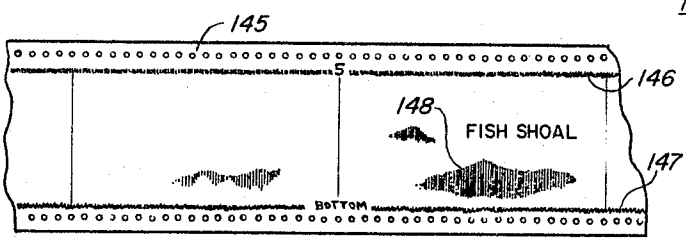


FIG. 9



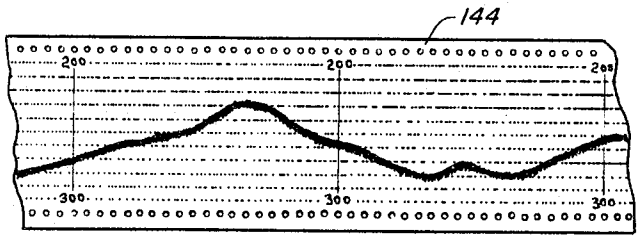
SURFACE REFERENCE OPERATION

FIG. 11



BOTTOM REFERENCE OPERATION

FIG. 12



DEPTH INTERVAL OPERATION

FIG. 13

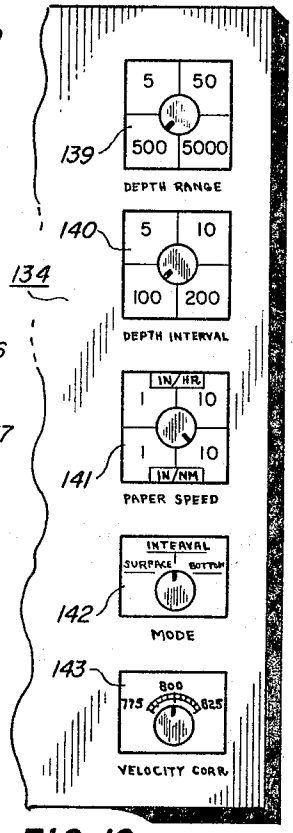


FIG. 10

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United States Patent Office

3,324,451

Patented June 6, 1967

3,324,451

ECHO RANGING AND RECORDING APPARATUS

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Filed June 3, 1964, Ser. No. 372,186

8 Claims. (Cl. 340—3)

The present invention relates to echo ranging and recording apparatus having greatly improved characteristics and capabilities over the prior art.

In the past, echo ranging recorders have consisted of a mechanical stylus traveling repetitively across a paper strip; means for triggering a transmitted pulse as the stylus passes the reference edge of the paper; and means for marking the paper coincident with received echoes so that the lateral displacement of the mark is proportional to the distance to a reflecting object. These echo ranging recorders have been fraught with numerous disadvantages and problems because of the inherent limitations of the mechanical stylus systems.

It is the principal object of the present invention to provide echo ranging and recording apparatus which overcomes those operational limitations in the prior art which were concomitant with the use of mechanical styli.

The present invention provides an echo ranging and recording system in which a cathode ray tube replaces the conventional mechanical stylus. Triggering, gating, and range marks are provided by clock pulses divided down from a reference oscillator frequency which is proportional to the velocity of sound in the medium. The high resolution and precision timing capabilities of the system make possible a high degree of accuracy on a relatively narrow recording paper. Corrections for variations of sound velocity in the medium can be easily made by adjustment of the reference oscillator frequency. The unlimited writing speed capabilities of the cathode ray tube allows the inclusion of a very shallow range scale for harbor approaches and channels. The random triggering capabilities of the cathode ray tube sweep allows the system to be used as a net depth recorder simultaneous with normal use. In a preferred embodiment of the invention, automatic range interval identification is provided for the expanded sweep mode of operation.

Other objects and advantages of the present invention will become more apparent from the following specifications and claims in which:

FIGURE 1 is a schematic and block diagram of an echo ranging and recording system according to the present invention.

FIGURE 2 is a top view of the graphic recorder used with the apparatus of FIGURE 1.

FIGURE 3 shows the time sequence of pulses generated by the apparatus of FIGURE 1.

FIGURE 4 shows the pulse characteristics of the apparatus of FIGURE 1 for various depth ranges.

FIGURE 5 shows an alternate graphic recording technique for the echo ranging system along with proportional paper speed and pulse rate controls.

FIGURE 6 shows another alternate graphic recording technique for the echo ranging system.

FIGURE 7 shows a double pulse echo ranging and recording system according to the present invention.

FIGURE 8 shows the pulse sequence for the operation of the double pulse echo ranging and recording system shown in FIGURE 7.

FIGURE 9 shows a front view of the echo ranging and recording apparatus.

FIGURE 10 shows in more detail the various controls for the echo ranging recorder of FIGURE 9.

FIGURE 11 shows a typical echo ranging record for surface reference operation.

FIGURE 12 shows a typical echo ranging record for bottom reference operation.

FIGURE 13 shows a typical echo ranging record for depth interval operation.

In FIGURE 1 a repetitive trigger pulse source 7 is shown having an output synchronized with the pulses from the timing pulse source 20. The various timing pulse sources 19–21 are divided down by steps of ten from the reference timing pulse generator 18. The frequency of the timing pulse generator 18 is proportional to the velocity of sound in water and its frequency may be adjusted correspondingly. For example the output frequency should be 400 pulses per second for an expected sound velocity of 800 fathoms per second when the depth is to be read in units of fathoms. When the multivibrator 8 is triggered by a pulse from the rate generator 7, the gate 2 is opened for the duration of the multivibrator 8 pulse length. When the gate 2 is opened the output of the oscillator 1 is fed into the transmit amplifier 3. The amplified pulse is transmitted into the water by means of the transmitting transducer 4. Reflected signals are picked up by the receiving transducer 5 and amplified by the receiving amplifier 6. The amplified received signals drive the intensity modulator 12 so that the intensity of the electron beam of the cathode ray tube 13 is proportional to the intensity of acoustic signals received by the transducer 5. The trigger pulses from the rate generator 7 are also used to trigger the sweep interval multivibrator 9. The duration of the output of the multivibrator 9 determines the display interval of the cathode ray tube 13. The sweep generator 10 produces a sawtooth wave which drives the vertical deflection amplifier 11. The electron beam of the cathode ray tube 13 is thus deflected in a linear manner so that displacement along the faceplate can be used as a measure of elapsed time. Since the sweep is initiated at the same instant that the acoustic pulse is transmitted, and since the received echoes are used to intensity modulate the electron beam, the elapsed time interval may be represented by a scaled distance along the faceplate with a zero reference at the point of origin. A fibre optic matrix 14 is mounted within the faceplate of the cathode ray tube 13. A "phosphor" 25 coats the inner surface of the fibre optic matrix 14.

FIGURE 2 shows a top view of the cathode ray tube 13. A roll 27 of photosensitive paper 26 is pulled along past the outer end of the fibre optic matrix 14 by means of the motor 29. The photosensitive emulsion on the paper strip 26 is thus exposed by the light output of the "phosphor" 25 when activated by the electron beam.

FIGURE 3 shows the time sequence of pulses for the operation of the apparatus of FIGURE 1. Reference timing pulses 36 of 400 c./s. are shown which correspond to a sound velocity of 800 fathoms per second. These pulses are divided down in steps of ten to one to obtain timing or clock pulses of 40 c./s., 4 c./s., and 0.4 c./s. The 4 c./s. pulses 38 are used as time marker pulses and also to synchronize the transmit trigger pulse 40. The resulting transmit pulse 41 corresponds in time and duration to the acoustic pulse transmitted into the water. The sweep multivibrator output 42 is also initiated by the trigger pulse 40. The vertical deflection waveform 43 deflects the electron beam across the full length of the faceplate so that the sweep interval is 1.25 seconds. The received signals are the direct pulse 44 and the bottom reflected pulse 45. The output pulses from the intensity modulator 12 include the direct pulses 46, the reflected pulse 48, and a series of 4 c./s. timing pulses 47. The timing pulses 47 are used as 100 fathom marks so that the depth of water may be determined by the displacement of the echo pulse 48 from the sweep origin.

FIGURE 4 shows pulse repetition rates, sweep inter-

vals, and marker frequencies which may be used for various depth ranges.

FIGURE 5 shows an alternate method for obtaining a graphic record of the cathode ray tube **50** output. The electron beam activates a suitable "phosphor" coating **51** which covers the inner surface of a fibre optic matrix **52** mounted within the faceplate of the cathode ray tube **50**. A roll **54** of photosensitive paper **53** is pulled past the outer surface of the fibre optic matrix **52** by means of the motor **58**. The photosensitive emulsion of the paper **53** is on the inner side against the fibre optic matrix **52**. The paper **53** is translucent or transparent so that the darkened portions of the emulsion may be readily seen. An electroluminescent panel **55** is positioned behind the exposed section of the paper strip **53** so that the recorded information may be seen in greater contrast. The digital motor **58** is driven at a rate proportional to the speed of the vessel on which the depth recorder is mounted. If a Doppler log is used, the varying frequency output may be used to drive the digtal motor. The digital motor **58** is also used to drive the rotary switch **60**. The rotary switch **60** is used to trigger the transmitted pulses at a rate proportional to the speed of the ship through the water.

FIGURE 6 shows another alternate method for obtaining a graphic record from a cathode ray tube. A cathode ray tube **63** is shown with a copper strip target **67** adjacent a beryllium strip window **66**. The target and window combination are elongated and positioned along the center of a face plate similar to the fibre optic matrix shown in FIGURE 1. A photosensitive paper **64**, having the emulsion side **65** on the side away from the tube face-plate, is pulled past the beryllium window **66**. A metal strip **68** is positioned opposite the beryllium window **66**. A "phosphor" material **69** is positioned against the photosensitive emulsion **65** opposite the beryllium window **66** by means of the metal strip **68**. When the electron beam strikes the copper traget **67**, X-rays are produced which penetrate the beryllium window **66** and the paper **64**. When the X-rays strike the "phosphor" **69** light is produced which "exposes" the photosensitive emulsion **65** on the paper strip **64**. A "phosphor" **69** is used which has a characteristic radiation corresponding to the peak sensitivity of the photosensitive emulsion **65**. The metal strips **68** absorbs the soft characteristic X-rays from the copper thereby providing adequate shielding for the operator of the echo sounder.

FIGURE 7 shows a preferred embodiment of the present invention wherein echoes from a relatively narrow depth interval are recorded. A double pulse system assures that only that interval containing the bottom echo will be recorded. The operation of the apparatus of FIGURE 7 may be more easily understood by reference to the corresponding pulse sequence diagram of FIGURE 8. The pulse sequence may be initiated either periodically or randomly. In FIGURE 7 a repetition rate pulse generator **83** turns on the flip flop **82** which simultaneously opens the gate **81**. When the gate **81** is open, the 4 c./s. clock pulses from the pulse source **98** are passed through the gate **81**. Each of the 4 c./s. pulses that pass through the gate **81** triggers the pulse length multivibrator **80** which opens the gate **72** for a brief interval. The resulting pulse from the output of the oscillator **71** is amplified and transmitted into the water by means of the amplifier **73** and the transmitting transducer **74**. The first 4 c./s. pulse to pass through the gate **81** turns on the flip flop **84** and the flip flop **86**. The second 4 c./s. pulse to pass through the gate **81** turns off the flip flop **84**. When the flip flop **84** is thus turned off, the flip flop **82** is simultaneously also turned off thereby closing the gate **81**. The result of the above sequence of operation is that each transmission, as initiated by the repetition rate generator or other trigger source, consists of a pair of pulses synchronized with two succesive 4 c./s. pulses divided down from the clock pulse generator **96**. In the above sequence of operations the flip flop **86** was left in the on condition. The flip flop remains on until switched off simultaneously with the reception of the first bottom echo. When the flip flop **86** is on, the gate **87** is open and passing 4 c./s. pulses to the counter **90**. The counter **90** thus counts the number of 4 c./s. pulses which occur between the transmission of the first transmitted pulse and the reception of the first bottom echo. Since each 4 c./s. pulse represents 100 fathoms of depth, the accumulated count shows in digital form the number of hundreds of fathoms of depth. The graphic recorder section of the depth sounder records only the fractional portion of the final hundred fathoms of depth which includes the bottom echo.

When the bottom echoes are received by the receiving transducer **75** they are amplified by the receiving amplifier **76** and coincident pulses are generated by the Schmitt trigger **85**. The pulse resulting from the first bottom echo triggers the multivibrator **78** to the quasi-stable state thereby opening the gate **79**. The quasi-stable period of the multivibrator is preset to keep the gate **79** open long enough to pass only two 4 c./s. pulses. In this case the period of the multivibrator **78** should be about 0.7 second. As a result of the above described sequence of operations, only the first two 4 c./s. pulses which occur (after the reception of the first bottom echo) are passed through the gate **79**. The first of these pulses turns on the flip flop **88** and the second turns off the flip flop **88**. Thus the on period of the flip flop **88** is precisely the time interval between the two 4 c./s. pulses which occur immediately following the reception of the first bottom echo. The sweep generator **89** produces a sawtooth output which drives the vertical deflection amplifier **94**. Thus a precise 100 fathom wide sweep is displayed on the face of the cathode ray tube **91**. Obviously the second bottom echo must arrive sometime during this 100 fm. sweep, and, as can be readily seen from the pulse diagram of FIGURE 8, the position of the second bottom echo along the scanned interval shows the fractional part of the final 100 fathoms to give the total depth of water. The total depth is found by noting the number of 100 fathom intervals accumulated on the counter and adding the fractional part of the final 100 fathom interval as recorded graphically. Any of the graphic recording methods shown in FIGURES 2, 5, or 6 may be used with the cathode ray tube **91**.

An alternate use of the apparatus of FIGURE 7 would be to display a fixed increment of distance above the bottom. The switch **101** should be turned to the bottom reference position. In this position, the flip flop **88** is turned on by the first bottom echo and turned off by the second bottom echo. In this manner the 100 fathom interval above the bottom is displayed by the cathode ray tube **91**. This type of display is useful when observing the position of objects, such as fish shoals, relative to the ocean bottom.

The output from the receiving amplifier **76** may be used to drive the intensity modulator **95**. As an alternative, the trigger **85** output may be used to give uniform size bottom marks on the graphic record paper. Depth maker pulses are also used to modulate the intensity of the electron beam. The 40 c./s. marker pulses from the pulse source **97** are used to mark 10 fathom increments on the graphic record for the surface reference or depth interval mode of operation. The reference frequency oscillator **96** may be varied by means of the control **100** so that the timing pulses correspond to the velocity of sound in water. A typical value would be a frequency of 400 c./s. which corresponds to a velocity of 800 fathoms per second. If units of feet are desired for the depth scale, the reference oscillator should be 2400 c./s. for a velocity of 4800 ft./sec. It may be readily seen therefore that any units of depth may be easily provided. It is only necessary that the reference oscillator frequency be selected accordingly. Thus a gross selection of the reference oscillator frequency may be used to select the desired depth units (fathoms, feet, or meters) and a fine adjustment of

the reference oscillator frequency is used to compensate for sound velocity changes in the medium.

FIGURE 8 shows the time sequence of operation of the apparatus of FIGURE 7. The 40 c./s. and 4 c./s. pulses are divided down from the reference oscillator **96**. A periodic (or random) trigger pulse **110** turns on the flip flop **82** which generates the output pulse **111**. The flip flop **82** is turned off by the second 4 c./s. pulse which occurs after it is turned on. The gate **81** is open by the output **111** of the flip flop **82** so that two transmit pulses **114** and **115** are triggered by the two 4 c./s. clock pulses which are allowed to pass. After the pulses **114** and **115** are transmitted into the water two bottom echoes **116** and **117** are received. The first bottom echo **116** triggers the multivibrator **78** to the quasi-stable state represented by the pulse **120**. The duration of the pulse **120** is sufficient to encompass two 4 c./s. clock pulses **108** and **109** which are allowed to pass through the gate **79**. The first 4 c./s. clock pulse **108** turns on the flip flop **88** and the second turns off the flip flop **88**. The output of the flip flop **88** is represented by the pulse **121** and this pulse is integrated to generate the sawtooth **122** which drives the vertical deflection amplifier **94**. The intensity modulator **95** is modulated by the second received bottom echo **128** and the 40 c./s. (10 fathom) marker pulses **123**. The flip flop **86** output pulse **124** represents the time interval between the first transmitted pulse **114** and the first received echo **116**. The 4 c./s. clock pulses are allowed to pass through the gate **87** for the duration of the pulse **124** so that the two clock pulses **126** and **127** are counted by the counter/printer **90** to give an indication of 100 fathom intervals of depth.

The series of pulses at the bottom of FIGURE 8 shows the bottom reference mode of operation. The sweep flip flop **88** pulse **129** is turned on by the first bottom echo **118** and turned off by the second bottom echo **119**. The sawtooth wave **130** drives the vertical deflection amplifier **94** to scan the 100 fathom interval above the bottom. The scanned interval thus begins with the first bottom echo and terminates with the second bottom echo **131**. Since the second bottom echo **131** is always at the end of the sweep, a graphic record is made of all reflecting objects in the 100 fathom interval adjacent the bottom. Obviously other intervals could be used. For example, a 10 fathom interval could be displayed by using the 40 c./s. clock pulses in place of the 4 c./s. clock pulses.

FIGURE 9 shows the exterior view **134** of an echo ranging recorder according to the present invention. A printing head **135** periodically prints the accumulated count of the counter **90**. A second printing head **136** may be used to print the accumulated count plus 100 fathoms for the bottom margin of the depth interval. The bottom profile **138** is shown within the 200 to 300 fathom interval and the exact depth may be read relative to the 10 fathom grid lines which are printed by the repetitive 40 c./s. time marker pulses. The photosensitive paper **144** may be utilized in any one of the print out techniques shown in the other drawings.

FIGURE 10 shows the various controls for the echo sounder including the depth range switch **139**, the depth interval switch **140**, the paper speed switch **141**, the operation mode selector switch **142** and the velocity correction adjustment **143**. The paper speed may be proportional to either time or ship speed.

FIGURE 11 shows a graphic record using the surface reference mode of operation as described by FIGURES 1 and 3. The depth of the bottom profile **150** is read relative to zero reference at the upper margin of the recording paper in the conventional manner. The series of depth marks **151** show the progress of a fish net as it is lowered to just below 200 fathoms and then retrieved back to the surface. A device attached to the fish net periodically transmits a pair of pulses the time interval between which is proportional to depth (for example 2.5 milliseconds for each fathom of depth). The first pulse to be received would trigger the CRT sweep and the second pulse would intensity modulate the electron beam. These pulses could be made easily identifiable by a slight transverse deflection of the electron beam coincident with the intensity modulation.

FIGURE 12 shows a typical graphic record **145** from the bottom reference mode of operation. The bottom trace **147** always appears flat along the bottom margin of the paper. A five fathom interval above the bottom is displayed and a fish shoal **148** near the bottom is shown.

FIGURE 13 shows a typical graphic record **144** of the depth interval mode of operation as described previously.

The echo ranging and recording apparatus described herein is particularly useful for measuring and recording the depth of the ocean. Other applications include nondestructive testing and medical diagnostic ultrasonic pulse echo systems.

The photosensitive recording paper used with the echo ranging recorder develops a visible trace without the need for chemical treatment. Several varieties of direct print paper are commercially available and they are commonly used with mirror galvanometer type graphic recorders. Some of these photographic papers are sensitive only to ultraviolet light. The wavelength of the light emission of the "phosphor" should correspond to the peak sensitivity of the photosensitive paper. If the latent image is heated to about 250° F. followed by exposure to strong light, the image can be made visible within a few seconds. A heater element **31** is used in the apparatus of FIGURE 2 to heat the exposed section of the recording paper **26** before latensification by the ambient light. As an alternative, a suitable light source can be used to illuminate the paper record to further increase the rate of image latensification.

It may be readily seen therefore that the above described echo ranging and recording apparatus provides many advantages over the prior art. The automatic depth interval identification feature using the double pulse mode of operation allows the depth sounder to be used for precision depth survey work without constant attention for range switching. The recorded bottom trace obviously cannot run off scale and numerous intervals of depth are not recorded on top of each other. Problems of multiple bottom echoes and scattering layers are largely eliminated. When echo sounding in deep water much higher pulse repetition rates may be used with this apparatus than with the conventional echo sounders. Many pairs of pulses may be simultaneously in transit between the surface and the bottom. This would assume, of course, that the 100 fathom interval counter and printer would not be used for each transmitted pair of pulses as it is necessary to determine the depth range (i.e. identify the 100 fathom interval) only infrequently relative to the pulse repetition rate. The above described apparatus may be easily adapted for the digital display of depth. It is only necessary, for example, that the 400 c./s. pulses be gated and counted during the time interval between transmission of a pulse and reception of the bottom echo. This would be accomplished by feeding the 400 c./s. pulses into the gate **87** and totalizing the gated pulses on a digital counter. The depth would then be digitally displayed in fathoms.

The particular embodiments of the invention ilustrated and described herein are illustrative only, and the invention includes such other modifications and equivalents as may readily appear to those skilled in the art, within the scope of the appended claims.

What is claimed is:

1. Echo ranging and recording apparatus comprising: a timing pulse generator having an output frequency numerically related to the velocity of acoustic waves in a medium; means for transmitting a first and second acoustic pulse into the medium coincident with two consecutive timing pulses from the said timing pulse generator; means for receiving first and second acoustic

pulses from within the said medium resulting from reflections of the said transmitted pulses; a cathode ray tube including means for deflecting an axial beam of electrons laterally along the axis of an elongated faceplate in response to a triangular wave; a sweep generator having a triangular wave output; means for initiating the triangular wave output of the said sweep generator coincident with the first timing pulse from the said timing pulse generator to occur after the reception of the first of the said received acoustic pulses; means for terminating the triangular wave output of the said sweep generator coincident with the second consecutive timing pulse from the said timing pulse generator to occur after the reception of the said first received acoustic pulse; means for intensifying the electron beam current of the said cathode ray tube coincident with the second of the said received acoustic pulses; an elongated target element on the inner surface of the said cathode ray tube faceplate for converting the energy of the said electron beam into electromagnetic radiation, the said target element being disposed along the sweep axis of the aforementioned electron beam; an elongated transparent element disposed adjacent the said target element for passing the said electromagnetic radiation through the aforementioned faceplate; an elongated paper strip having a photosensitive surface disposed against the outer surface of the said transparent element, a visible mark being thereby printed on the said paper when the electron beam is intensified; and means for moving the said paper strip across the outer surface of the said transparent element.

2. Echo ranging and recording apparatus comprising: a timing pulse generator for producing a first series of timing pulses having a frequency which is related numerically to the velocity of acoustic waves in a medium; means for dividing down the said first series of timing pulses to produce a second series of timing pulses having a frequency which is a sub-multiple of the said first series; means for transmitting a first acoustic pulse into the medium coincident with a first timing pulse from the said second series of timing pulses; means for transmitting a second acuostic pulse into the medium coincident with a second consecutive timing pulse from the said second series of timing pulses; means for receiving first and second acoustic pulses from the said medium resulting from reflections of the said transmitted pulses; a cathode ray tube having means for deflecting an axial beam of electrons laterally along the axis of an elongated faceplate in response to a triangular wave; a sweep generator having a triangular wave output; a normally closed gate circuit for passing timing pulses from the said second series of timing pulses; means for opening the said gate circuit coincident with the reception of the first of the said received acoustic pulses, the said gate remaining open for a predetermined period; means for initiating the triangular wave output from the said sweep generator coincident with the first timing pulse to pass through the said gate; means for terminating the triangular wave output from the said sweep generator coincident with the second consecutive timing pulse to pass through the said gate; means for intensifying the electron beam current of the said cathode ray tube coincident with the second of the said received acoustic pulses; means for intensifying the electron beam current of the said cathode ray tube coincident with timing pulses from the said first series of timing pulses; an elongated fibre optic matrix within the said cathode ray tube faceplate, the said matrix being disposed along the sweep axis of the aforementioned electron beam; a luminescent phosphor material covering the inner surface of the said fibre optic matrix, the said phosphor emitting light of a characteristic wavelength when excited by the aforementioned electron beam; an elongated paper strip having a photosensitive surface disposed against the outer surface of the said matrix, a visible mark being thereby printed on the said paper when the aforementioned electron beam is intensified; and means for moving the said paper strip across the outer surface of the said matrix.

3. Echo ranging and recording apparatus comprising: a timing pulse generator for producing a series of timing pulses having a frequency numerically related to the velocity of acoustic waves in a medium; means for transmitting a first acoustic pulse into the medium coincident with a first timing pulse from the said timing pulse generator; means for transmitting a second acoustic pulse into the medium coincident with a second consecutive timing pulse from the said timing pulse generator; means for receiving first and second acoustic pulses from the said medium resulting from reflections of the said transmitted pulses; a cathode ray tube having means for deflecting an axial beam of electrons laterally along the axis of an elongated faceplate in response to a triangular wave; a sweep generator having a triangular wave output; a first gate circuit for passing timing pulses from the said timing pulse generator; means for opening the said first gate circuit coincident with the reception of the first of the said received acoustic pulses, the said first gate circuit remaining open for a predetermined interval; means for initiating the said sweep generator coincident with the first timing pulse to pass through the said first gate circuit; means for terminating the said sweep generator coincident with the second consecutive timing pulse to pass through the said first gate circuit; means for intensifying the electron beam current of the said cathode ray tube coincident with the second of the said received acoustic pulses; a second gate circuit for passing timing pulses from the said timing pulse generator; means for opening the said second gate circuit coincident with the transmission of the said first acoustic pulse; means for closing the said second gate circuit coincident with the reception of the first of the said received acoustic pulses; means for counting the number of said timing pulses passed by the said second gate circuit; an elongated fibre optic matrix within the said cathode ray tube faceplate, the said matrix being disposed along the sweep axis of the aforementioned electron beam; a luminescent phosphor material covering the inner surface of the said fibre optic matrix, the said phosphor emitting light of a characteristic wavelength when excited by the aforementioned electron beam; an elongated paper strip having a photosensitive surface disposed against the outer surface of the said matrix, a visible mark being thereby printed on the said paper when the aforementioned electron beam is intensified; and means for moving the said paper strip across the outer surface of the said matrix.

4. Apparatus of the character described comprising: a clock pulse generator having a nominal output frequency numerically related to the velocity of acoustic waves in a medium; means for adjusting the frequency of the said clock pulse generator to compensate for known variations in the velocity of acoustic waves in the medium; means for transmitting a first acoustic pulse into the medium coincident with a first clock pulse from the said clock pulse generator; means for transmitting a second acoustic pulse into the medium coincident with a second consecutive clock pulse from the said clock pulse generator; means for receiving first and second acoustic pulses from the said medium resulting from reflections of the said transmitted pulses; a cathode ray tube having means for deflecting an axial beam of electrons along the axis of an elongated faceplate in response to a triangular wave; a sweep generator having a triangular wave output; a normally closed gate circuit for passing the said clock pulses; means for opening the said gate circuit coincident with the reception of the first of the said received pulses, the said gate circuit remaining open for a predetermined interval; means for initiating the said sweep generator output coincident with the first clock pulse passed through the gate; means for terminating the said sweep generator output with the second consecutive clock pulse passed through the said gate; means for intensifying the electron

beam current of the said cathode ray tube coincident with the second of the said received acoustic pulses; an elongated fibre optic matrix within the said cathode ray tube faceplate, the said matrix being disposed along the sweep axis of the aforementioned electron beam; a luminescent phosphor material covering the inner surface of the said matrix, the said phosphor emitting light of a characteristic wavelength when excited by the electron beam; an elongated paper strip having a photosensitive surface disposed against the outer surface of the said matrix, a visible mark being thereby printed on the said paper when the aforementioned electron beam is intensified; and means for moving the said paper strip across the outer surface of the said fibre optic matrix.

5. Apparatus of the character described comprising: a timing pulse generator for producing a first series of timing pulses having a frequency numerically related to the velocity of acoustic waves in water; means for dividing down the said first series of timing pulses to produce a second series of timing pulses having a frequency which is a submultiple of the said first series; means for transmitting a first acoustic pulse into the water coincident with a first timing pulse from the said second series of timing pulses; means for transmitting a second acoustic pulse into the water coincident with a second consecutive timing pulse from the said second series of timing pulses; means for receiving acoustic pulses from the said water including first and second acoustic pulses resulting from reflections of the said transmitted pulses; a cathode ray tube having means for deflecting a beam of electrons laterally along the major axis of an elongated faceplate in response to a sweep waveform; a sweep waveform generator; a first normally closed gate circuit for passing the said second series of timing pulses; means for opening the said gate circuit coincident with the reception of the first of the said received acoustic pulses, the said first gate circuit remaining open for a predetermined suitable interval; means for initiating the said sweep waveform generator coincident with the first timing pulse passed by the said first gate; means for terminating the said sweep waveform generator with the second consecutive timing pulse passed by the said first gate; means for intensifying the electron beam current of the said cathode ray tube coincident with the second of the said received acoustic pulses; a second normally closed gate circuit for passing timing pulses from the said second series of timing pulses; means for opening the said second gate coincident with the transmission of the said first acoustic pulse; means for closing the said second gate coincident with the reception of the first of the said received acoustic pulses; means for counting the said timing pulses passed by the said second gate circuit; means for intensifying the electron beam current of the said cathode ray tube coincident with timing pulses from the said first series of timing pulses; an elongated target element on the inner surface of the said cathode ray tube faceplate, for converting electron beam energy into electromagnetic radiation, the said target element being disposed along the sweep axis of the aforementioned electron beam; a transparent element disposed adjacent the said target element for passing the emitted electromagnetic radiation through the said faceplate; an elongated paper strip having a photosensitive surface disposed against the outer surface of the said transparent element, a visible mark being thereby printed on the said paper when the said electron beam is intensified; and means for moving the said paper strip across the said faceplate.

6. Echo ranging and recording apparatus comprising: a clock pulse generator having an output frequency numerically related to the velocity of acoustic waves in water; means for transmitting a first acoustic pulse into a water medium coincident with a first clock pulse from the said pulse generator; means for transmitting a second acoustic pulse into a water medium coincident with a second consecutive clock pulse from the said pulse generator; means for receiving acoustic pulses from a water medium including first and second pulses resulting from reflections of the said transmitted pulses; a cathode ray tube having means for deflecting a beam of electrons along the major axis of an elongated faceplate in response to a triangular wave; a normally quiescent sweep generator having a triangular wave output; a normally closed gate circuit for passing the said clock pulses; means for opening the said gate circuit coincident with the reception of the first of the said received acoustic pulses, the said gate circuit remaining open for a predetermined suitable interval; means for initiating the said sweep generator coincident with the first clock pulse passed by the said gate; means for terminating the said sweep generator with the second consecutive clock pulse passed by the said gate; means for intensifying the electron beam current of the said cathode ray tube coincident with the second of the said received acoustic pulses; an elongated fibre optic matrix within the said faceplate, the said matrix being disposed along the sweep axis of the aforementioned electron beam; a luminescent phosphor material covering the inner surface of the said matrix, the said phosphor emitting light when excited by the said electron beam; an elongated paper strip having a photosensitive surface disposed against the outer surface of the said matrix, a visible mark being thereby printed on the said paper when the said electron beam is intensified; a trigger pulse generator for initiating the aforementioned double pulse transmission sequence; a digital pulse motor for moving the said paper strip across the outer surface of the said fibre optic matrix; a source of electrical pulses having a rate proportional to the speed of a ship through the water; means for driving the said digital motor with the said electrical pulses; and means for driving the said trigger pulse generator at a rate proportional to the speed of the said digital motor.

7. The method of graphically recording the distance to sound reflecting objects in a medium which comprises: generating a series of timing pulses having a repetition rate numerically related to the velocity of sound in a medium; transmitting first and second acoustic pulses into the medium coincident with first and second timing pulses from the said series of timing pulses; receiving first and second acoustic pulses from within the said medium resulting from reflections of the said transmitted acoustic pulses; initiating the sweep waveform of a cathode ray tube coincident with the first timing pulse to occur after the reception of the first acoustic pulse of the said received first and second acoustic pulses; intensity modulating the electron beam current of the said cathode ray tube coincident with the reception of the second acoustic pulse of the said received first and second acoustic pulses; terminating the aforementioned sweep waveform coincident with a timing pulse from the said series of timing pulses; translating electron beam intensity variations impinging on the inner surface to corresponding light variations on the outer surface of the said cathode ray tube faceplate by means of a luminescent phosphor and fiber optic matrix combination within the said faceplate; and continually passing a strip of photosensitive paper across the surface of the said faceplate so that a graphic record is obtained of the distance to reflecting objects in the medium.

8. The method of graphically recording the distance above the ocean bottom of sound reflecting objects in the ocean which comprises: generating a series of timing pulses having a repitition rate numerically related to the velocity of sound in the ocean; transmitting first and second acoustic pulses into the ocean coincident with a first and second timing pulse from the said series of timing pulses; receiving first and second acoustic pulses from within the ocean resulting from reflections from the ocean bottom and also from intermediate objects above the ocean bottom; initiating the sweep waveform of a cathode ray tube coincident with the reception of the first acoustic pulse of the said received first and second acoustic pulses reflected

from the ocean bottom; intensity modulating the electron beam current of the said cathode ray tube coincident with the reception of acoustic pulses resulting from reflections from objects above the ocean bottom; terminating the sweep waveform of the cathode ray tube coincident with the reception of the second acoustic pulse of the said received first and second acoustic pulses reflected from the ocean bottom; translating electron beam intensity variations impinging on the inner surface to corresponding light variations on the outer surface of the said cathode ray tube faceplate by means of a luminescent phosphor and fiber optic matrix combination within the said faceplate; and continually passing a strip of photosensitive paper across the surface of the said faceplate so that a graphic record is obtained of the distance of reflecting objects above the bottom of the ocean.

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