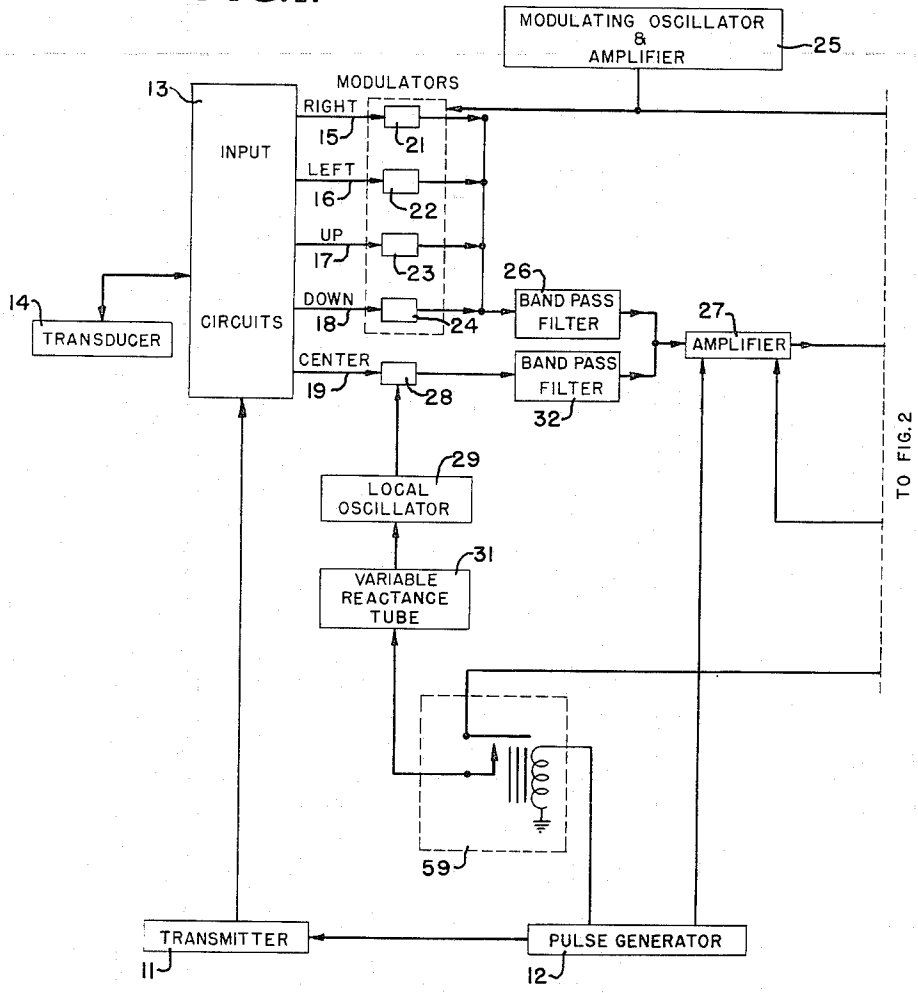
March 13, 1962 H. BROOKS 3,024,755

TORPEDO ECHO STEERING SYSTEM

Filed Aug. 3, 1951 3 Sheets-Sheet 1

FIG.1.



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TORPEDO ECHO STEERING SYSTEM

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FIG.2.

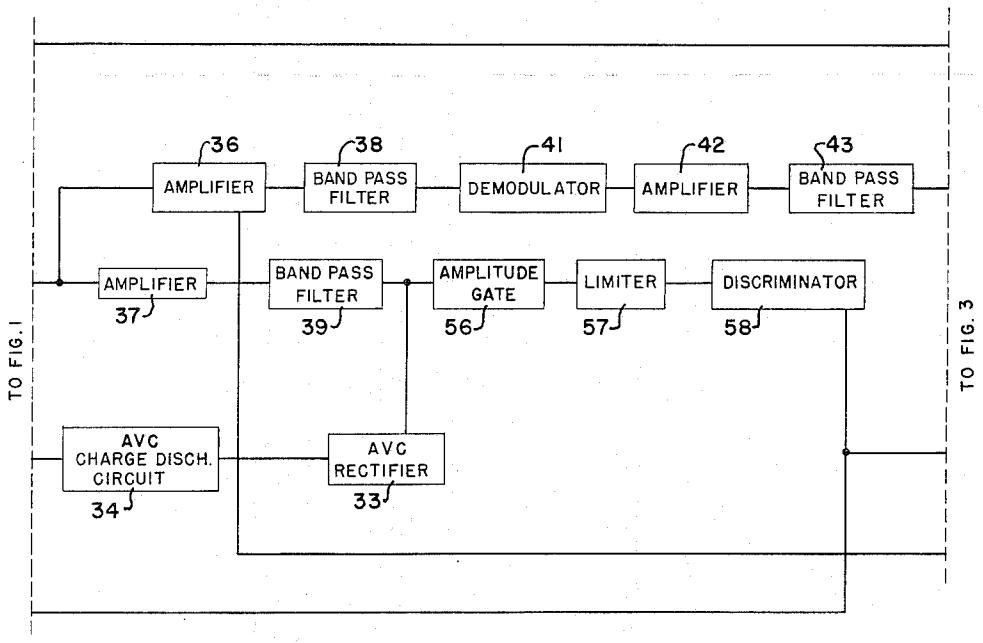
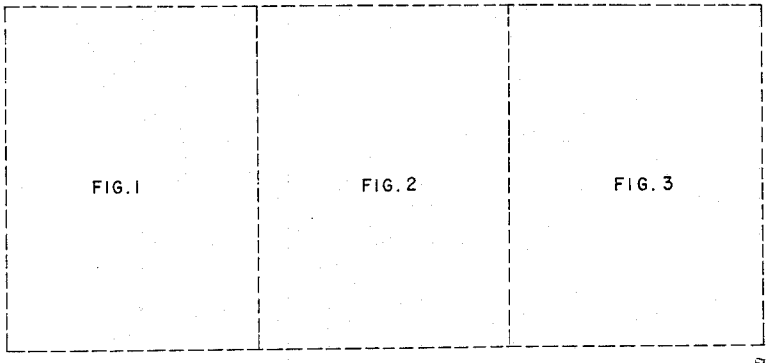


FIG.4.



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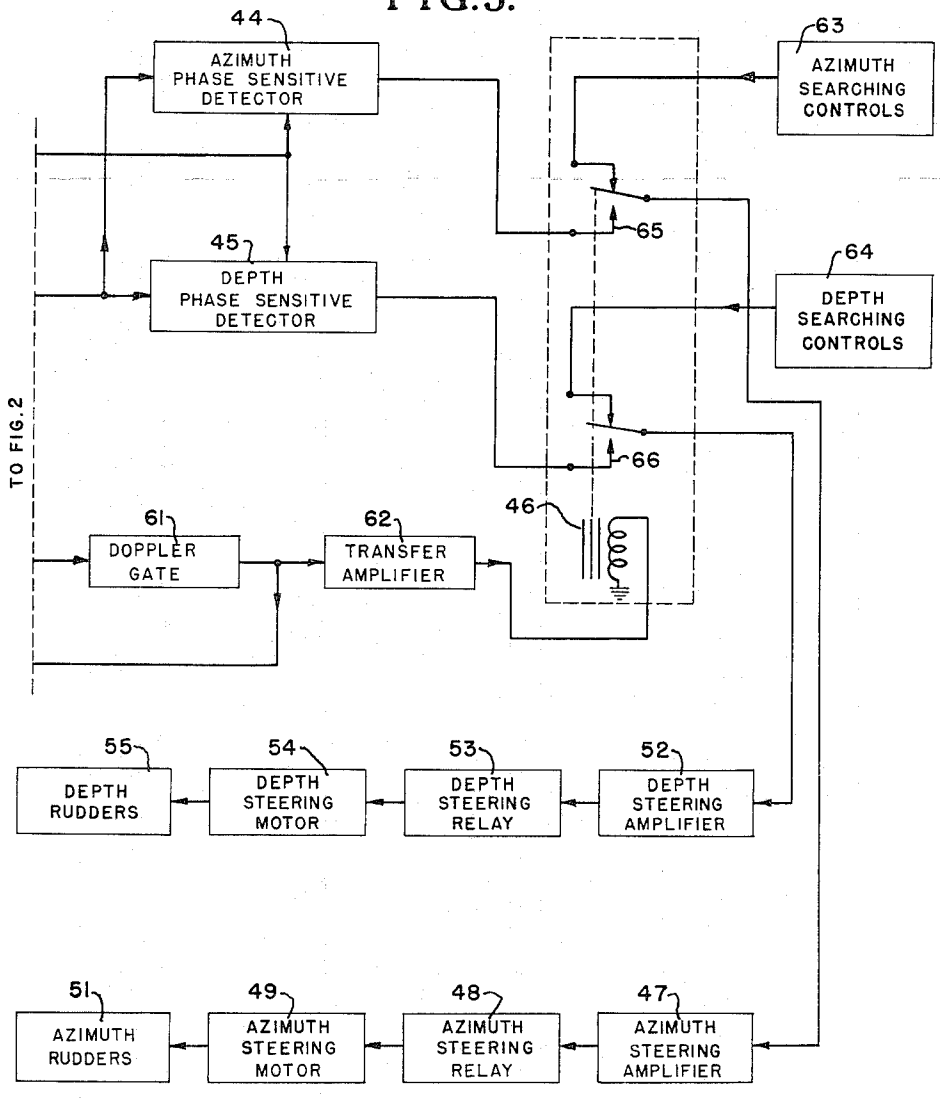
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TORPEDO ECHO STEERING SYSTEM

Filed Aug. 3, 1951 3 Sheets-Sheet 3

FIG.3.



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3,024,755

TORPEDO ECHO STEERING SYSTEM

Harvey Brooks, Cambridge, Mass., assignor to the United States of America as represented by the Secretary of the Navy

Filed Aug. 3, 1951, Ser. No. 240,213
10 Claims. (Cl. 114—23)

This invention relates generally to a system for steering a torpedo or similar device and more particularly to an acoustically steered mechanism which is actuated in response to an echo from a target as distinguished from a device which relies on target noise for its operation.

In prior art homing devices it has been well known to provide acoustic responsive devices which would receive noise from the propellers or other sound sources on a target vessel and utilize this received energy to orient the path of travel of the device in the direction from which the sound is received. Such devices have not been completely satisfactory in that they are susceptible to extraneous sounds such as decoy action and experience difficulty in homing on a quiet target such as a slowly moving submarine.

The present invention overcomes these disadvantages of prior art devices by providing a homing device which detects the presence of an object by echo-ranging means. The device of the present invention operates by transmitting energy intermittently into the water and between transmission periods receiving echo signals which are compared for horizontal and vertical guidance by split-lobe steering characteristics of the receiver.

The system of the present invention employs circuits which provide guidance only when echoes are received from a moving target and prevent unwanted signals such as those due to reverberation and noise from affecting the operation of the device. Provision is further made for compensation of the apparent doppler change due to the variations in the speed of the device itself and further circuits provide for a systematic search pattern throughout the space in which the device is orientated at any time during an attack in which no suitable echo signal is received from a desirable target.

An object of this invention is to provide a new and improved echo-steering system for a torpedo or similar device.

Another object of the invention is to provide an echo-steering system for a torpedo or similar device in which two dimensional guidance is derived from an echo from a target which is in motion relative to the water or other medium in which the device operates.

A further object of this invention is to provide an echo-steering system for a torpedo or similar device which is insensitive to noise or reverberation or echoes from stationary objects.

Another object of this invention is to provide an echo-steering system for a torpedo or similar device, which, when placed in operation, systematically searches throughout a predetermined space for a moving target and which, having received an echo from such a target, interrupts its searching procedure and utilizes information contained in the initial and succeeding target echoes to direct its course in the direction of the target.

A further object of this invention is to provide a guided device which when the reception of suitable signals is interrupted for any reason during an attack the device resumes a systematic searching procedure in an effort to recover reception of suitable signals.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. 1 is a block diagram of a portion of the system including the transmitter and transducer;

FIG. 2 is a block diagram of an intermediate portion of the system;

FIG. 3 is a block diagram of the final portion of the system which includes the controlled elements; and

FIG. 4 is a view showing the arrangements of FIGS. 1, 2 and 3 to obtain a complete block diagram of the system.

Referring now to the drawings, the invention will be described with reference to FIGS. 1, 2 and 3 as arranged according to FIG. 4. The circuits described are incorporated within a suitable self-propelled body such, for example, as a torpedo together with an explosive charge which may be detonated by suitable contact or by influence with the target and which may be launched into the water when the presence of a target submarine is suspected. The device may be launched from an airplane or, if suitable hydrostatic controls and a limited upward aspect search pattern are provided to prevent homing on a surface target, it may be launched from a surface vessel. The operative voltages are applied to the circuits by suitable arming means and a search of the surrounding medium is initiated by the echo-ranging system of the present invention.

A transmitter **11** generates pulses of alternating current at a suitable transmission frequency such, for example, as 60 kc. The pulse repetition rate of the transmitter is controlled by pulses provided by a suitable pulse generator **12** which, in addition, generates synchronized positive and negative pulses which are applied to other elements of the acoustic control system in a manner hereinafter described. Pulses of alternating current generated by the transmitter are applied to input circuits **13**, and thence to an electro-acoustic transducer **14**, so that pulses of acoustic energy are radiated at predetermined intervals.

The time intervals separating transmissions are known as listening periods. During such listening periods acoustic energy incident upon the transducer **14** comprises reverberation and echoes, the former of a predominant frequency differing from the transmission frequency by an amount which depends upon the speed of the torpedo and which amount is designated as own doppler, and the latter of a frequency which differs from the predominant frequency of reverberation by an amount known as target doppler. The amount of target doppler deviation from the predominant frequency depends upon the speed and course of the reflecting object and which amount is zero for objects at rest. The predominant frequency of reverberation is herein designated as signal frequency.

The acoustic energy incident upon transducer **14** following transmission produces alternating voltages at the output terminals of the transducer, the frequencies of which are equal to the frequency of the incident energy. The phase and amplitude relations among these output voltages are a measure of the direction from which the incident energy arrives when applied to the input circuits **13** which are arranged in the novel manner described and claimed in the copending application of Harvey Brooks for a Balanced Input Circuit for an Echo Ranging Receiver, Serial No. 263,807, filed December 28, 1951. U.S. Patent 2,524,180 to O.H. Schuck shows an example of a conventional device for determining the direction of arrival of incident energy which may also be used.

By means of input circuits **13**, five output voltages designated by right, left, up, down and center are produced. Each of these five voltages is of a frequency equal to the frequency of the energy incident upon the transducer and the arrangement of the input circuits is

such that the amplitudes of the right, left, up and down voltages produced by an echo from a target are a measure of the target bearing in azimuth and depth. In particular, the algebraic difference between the amplitudes of the right and left voltages is a measure of the target bearing in azimuth and the algebraic difference between the amplitudes of the up and down voltages is a measure of the target location in depth. The amplitude of the center voltage depends in part on the intensity of the energy incident upon the transducer.

The right, left, up and down voltages are applied respectively to the modulators **21**, **22**, **23** and **24**, respectively, which modulate these applied voltages by phased voltages of suitable frequency, say 1 kc., which are provided by the modulating oscillator and amplifier **25**. The output voltages provided by modulators **21**, **22**, **23** and **24** are combined, and the manner of operation of the modulators is such that the amplitude and phase of the modulation envelope of the combined output is a measure of the relative amplitudes of the right, left, up and down voltages.

The combined output of the modulators **21**, **22**, **23** and **24** is applied to a band pass filter **26** the pass band of which includes the signal frequency plus and minus an amount equal to the maximum frequency deviation expected from target doppler plus the frequency of the modulating voltages.

The output of the band pass filter **26** is applied to an amplifier **27** which is a broad band amplifier and which may be of conventional design.

Also applied to amplifier **27** is a voltage derived from the center voltage **19** by the action of a frequency converter. The circuits effecting frequency conversion employ a mixer **28** and a local oscillator **29** of conventional design and frequency of, say, 53 kc. such that the frequency of the derived voltage is equal to the difference between the frequencies of the local oscillator voltage and the center voltage **19**, while the amplitude of the derived voltage is proportional to the amplitude of the center voltage. The frequency of the derived voltage is herein called the reduced signal frequency and may be, for example, 7 kc. Moreover, the reduced signal frequency may be controlled by varying the frequency of the local oscillator **29** through the use of a variable reactance tube **31** and a frequency discriminator **58** in a manner hereinafter described.

A band pass filter **32** interposed between the mixer **28** and the input to amplifier **27** allows voltages at reduced signal frequency to pass, but attenuates voltages at other frequencies which also are present due to non-linear action of the mixer.

The amplifier **27** preferably has its gain reduced to zero during those time intervals when the transmitter is applying energy to the transducer. Such gain reduction may be effected by application to one or more grids of the amplifier tubes of a blanking pulse provided by the pulse generator **12** and synchronized with the pulses which are used to key the transmitter **11**.

Also associated with amplifier **27** are circuits which provide automatic control of gain in a manner designed to reduce the gain of the amplifier by an amount proportional to the intensity of the reverberation incident upon the transducer. Such automatic control of gain may be provided by an AVC rectifier **33** and an AVC charge-discharge circuit **34**. Said automatic control of gain may, however, be of any type which tends to maintain constant the amplitude of those components of amplifier output voltage that are due to the incidence of reverberation on the transducer, and may alternatively be of a type in which the gain of the amplifier is varied according to a predetermined function of time which is inversely related to the amplitude of a typical reverberation signal. In this case gain control may be provided by a voltage developed in the pulse generator **12** and applied to the amplifier by connections therebetween.

Regardless of the means by which automatic control of gain is provided, the gain control should not respond immediately to the initial blast of high intensity reverberation which immediately follows transmission, but should have a finite response time during which the amplitude of the reverberation signal at the output of the amplifier **27** is much larger than the constant amplitude imposed by the gain control system during the remainder of the listening period. The finite response time of the automatic gain control system is herein called the reverberation sampling time. The gain control after the reverberation sampling time should respond to the average value of the background level in the conventional manner in order that the short duration echo signals may be amplified and not appreciably reduce the gain to prevent their appearance at the output of amplifier **27**.

The output of amplifier **27** is applied to the inputs of amplifiers **36** and **37**. The outputs of amplifiers **36** and **37** are respectively applied to band pass filters **38** and **39**, the former of which has frequency transmission characteristics similar to band pass filter **26** and the latter of which has frequency transmission characteristics similar to band pass filter **32**. It will be appreciated at this point that the voltage at the output of band pass filter **39** is a voltage at reduced signal frequency; that said voltage is an amplifier replica of the voltage at the output of band pass filter **32**; that the amplitude of said voltage is substantially constant except during the reception of an echo the intensity of which is greater than the intensity of concurrent reverberation, and except during the reverberation sampling time at which time the amplitude is very large.

The amplifier **36** is designed to act both as an amplifier and an electronic switch; that is, it is normally nonconducting because of a large negative bias but in the presence of a doppler enabling pulse which sufficiently reduces the negative bias it functions as a conventional amplifier. Moreover, the operation of elements hereinafter described is such that a doppler enabling pulse is applied to the amplifier **36** only at such times as an echo is being received, and only in the event that the intensity of said echo is greater by a predetermined amount than the intensity of concurrent reverberation, and only in the event that the target doppler characterizing such echo is greater than a predetermined amount, and only in the event that the duration of said echo is greater than a predetermined length of time.

It will be further appreciated due to the circuits for deriving the doppler enabling pulse to be hereinafter described that the voltage appearing at the output of band pass filter **38** is zero except during the reception of an echo having all of the predetermined characteristics enumerated above; that during the reception of such an echo said voltage is a modulated signal, the modulation envelope of which is related as hereinbefore described in phase and amplitude to the direction from which the acoustic energy of the echo arrives at the transducer **14**.

The output of band pass filter **38** is applied to demodulator **41**, the output of which is a voltage identical to the modulation envelope of the voltage applied to the demodulator.

The output of demodulator **41** is applied to amplifier **42**, which may be an amplifier of conventional design.

The output of amplifier **42** is applied to band pass filter **43** which is designed to pass voltages of a frequency equal to that of the modulating voltage developed by the modulating oscillator and amplifier **25**, but which is designed to attenuate voltages of other frequencies.

The output of band pass filter **43** is applied to an azimuth phase sensitive detector **44** and to a depth phase sensitive detector **45**, which phase sensitive detectors are preferably of a type disclosed in the aforementioned patent application for a Four Channel Amplifier. To phase sensitive detectors **44** and **45** are also applied voltages which are provided by the modulating oscillator and

amplifier and which are of the same frequency as the modulating voltages applied to modulators 21, 22, 23, and 24. The characteristics of phase sensitive detectors 44 and 45 and modulators 21, 22, 23 and 24 are such that the output voltage of phase sensitive detector 45 is proportional to the algebraic difference between the amplitudes of the up and down voltages provided by the input circuits 13, and the output of phase sensitive detector 44 is proportional to the algebraic difference between the amplitudes of the right and left voltages provided by the input circuits 13 all in accordance with the teaching of the aforementioned patent application for a Four Channel Amplifier.

The output of phase sensitive detector 44 is applied to a contact 65 on transfer relay 46 and, provided this relay is energized, is applied to an azimuth steering amplifier 47 the output of which actuates an azimuth steering relay 48.

The steering relay 48 which may be one of a variety of relays employed in conventional electronically actuated relay circuits controls a steering motor 49 or similar device for positioning the azimuth steering rudders 51 of the torpedo. Moreover, the arrangement of the azimuth steering amplifier 47 and azimuth steering relay 48 is such that a voltage output of phase sensitive detector 44 of short duration will cause the torpedo to turn in azimuth in a direction toward the target which produced this voltage and continue to turn in this direction, even after the voltage output of phase sensitive detector 44 has disappeared, until such time as phase sensitive detector 44 again provides an azimuth steering voltage.

The output of phase sensitive detector 45 is applied to a contact 66 on transfer relay 46 and, provided this relay is energized, is applied to a depth steering amplifier 52 the output of which actuates a depth steering relay 53.

The relay 53 which may be one of a variety of relays employed in conventional electronically actuated relay circuits controls a steering motor 54 or similar device for positioning the depth steering rudders 55 of the torpedo. The arrangement of the depth steering amplifier 52 and the depth steering relay 53 is such that a voltage output of phase sensitive detector 45 of short duration will cause the torpedo to turn in depth in a direction toward the target which caused this voltage and continue to turn in this direction, even after the voltage output of phase sensitive detector 45 has disappeared, until such time as phase sensitive detector 45 again provides a depth steering voltage.

It will be appreciated at this point that the output of band pass filter 38 differs from zero only during such times as an echo of predetermined characteristics is being received; that the output of band pass filter 38 is utilized to guide the torpedo in azimuth and depth in the direction from which an echo arrives; that the output of band pass filter 38 is so used only in the event that a transfer relay 46 is energized.

The output of band pass filter 39 is applied to an amplitude gate 56 which is preferably of a type described in the patent application of A. N. Butz, Jr. and H. Brooks for an Echo Ranging Torpedo, Ser. No. 305,432 filed August 20, 1952. The characteristics of this circuit are similar to that of conventional gated amplifiers well known in the art such that its output voltage is zero when the amplitude of the applied voltage is less than a predetermined value and which has further characteristics such that its output voltage is an amplified replica of the applied voltage when the amplitude of the applied voltage is greater than said predetermined value thereby actuating the gate. The predetermined amplitude of applied voltage required to actuate the amplitude gate 56 is preferably selected through consideration of the characteristics of the automatic gain control circuits associated with common amplifier 27. Said predetermined value is preferably selected such that signals which represent reverberation do not actuate the amplitude gate except during the reverberation sampling period, but such that signals of amplitude slightly greater than the amplitude of concurrent reverberation do actuate the amplitude gate.

The output of amplitude gate 56 is applied to a limiter 57 which is an amplifier having characteristics such that the maximum possible output voltage is produced when the voltage applied to the amplitude gate 56 is just sufficient to make said amplitude gate conductive.

The output of limiter 57 is applied to a discriminator 58 which may be of conventional design and which provides an output voltage the instantaneous value of which is proportional to the algebraic difference between the frequency of the applied voltage and the characteristic frequency of the circuits of the discriminator, said output voltage being zero when the two frequencies are equal.

The voltage output of the frequency discriminator 58 is applied to other circuits of the acoustic control system in two ways as follows: (1) During the reverberation sampling period the output voltage is connected through an Own Dopple Nullifier (ODN) relay 59 to the variable reactance tube 31 which is associated with the local oscillator 29 and which is described above. During this time interval the discriminator voltage modifies the frequency of the local oscillator 29 in such a way as to make the reduced signal frequency equal to the characteristic frequency of the discriminator, thereby reducing the output voltage of the discriminator to zero. The proper operation of the ODN relay 59 is accomplished by applying to it a voltage pulse provided by the pulse generator 12 such that the relay is closed during the reverberation sampling period. The resultant effect of this action, known as own doppler nullification, is to make the reverberation signal at reduced signal frequency equal to the characteristic frequency of the discriminator regardless of variations of own doppler resulting from variations in the speed of the torpedo. Moreover, the time constants of the reactance tube circuit are long compared to the intervals between successive transmissions, thereby causing the frequency adjustment of the local oscillator to persist throughout the remainder of the listening period. (2) The output voltage of the discriminator 58 is applied to a doppler gate 61 which is preferably of a type described in the aforementioned patent application for a Doppler Discriminator Circuit. The characteristics of the doppler gate are such that its output voltage is of constant polarity regardless of the polarity of the voltage provided by the discriminator and is of zero magnitude if the discriminator voltage is less than a predetermined threshold value. Except for the unipolarity of the output voltage of 61 it is approximately an amplified replica of the voltage output of the discriminator if the voltage output thereof is greater than the threshold value of the doppler gate, and is maintained greater than the threshold value for more than some predetermined length of time. Because the voltage provided by the discriminator is proportional to the difference between the reduced signal frequency and the characteristic frequency of the discriminator, and because own doppler nullification maintains this frequency difference zero except during the reception of an echo from a moving target, in which case the frequency difference depends upon the speed and aspect of the target, it is convenient to express the threshold voltage required to obtain an output from the doppler gate in terms of target speed in knots. Thus, a characteristic of the doppler gate is that a signal representing an echo from a target causes a voltage output only if the velocity component of the target in the direction of the torpedo exceeds a predetermined value. The voltage output of doppler gate 61 is herein called the doppler enabling pulse.

The doppler enabling pulse is applied to the amplifier 36 in the manner hereinbefore described and allows amplifier 36 to supply steering signals to the rudder actuating mechanisms only when such signals are derived from an echo representing a target moving with a velocity com-

ponent greater than a minimum predetermined value. If during the reverberation sampling time the output voltage of the discriminator **58** supplying the doppler gate **61** should exceed the threshold voltage necessary for the generation of a doppler enabling pulse, a doppler enabling pulse would be generated even though no target echo is being received. To circumvent this possibility the threshold of the doppler gate expressed in knots is preferably adjusted to a value greater than the expected change in torpedo speed from one transmission to the next.

The doppler enabling pulse is applied to the input terminals of amplifier **62** and the amplifier responds to the presence of a doppler enabling pulse by energizing the transfer relay **46**, thereby establishing acoustic control. Moreover, the time constants of the transfer amplifier **62** and the transfer relay **46** are long compared to the time intervals separating successive transmissions with the result that the transfer relay remains actuated so long as doppler enabling pulses are received at regular intervals.

Actuation of the transfer relay **46** causes the acoustic steering signals provided by phase sensitive dectectors **44** and **45** to be applied to the steering amplifiers **47** and **52** via contacts **65** and **66** thereby making the acoustic control system operative. When not actuated the relay **46** serves to connect the steering amplifiers **47** and **52** to some other source of electrical control signals designated on FIG. 3 as searching controls **63** and **64**.

The searching controls **63** and **64** together with the steering amplifiers **47** and **52** and the steering relays **48** and **53** and the steering motors **49** and **54** are utilized to steer the torpedo in the absence of echoes from a moving target. The searching controls may be of any suitable design, such for example as the conventional gyroscopic steering device disclosed in U.S. Patent 1,121,563 to K. O. Leon dated December 15, 1914, but should preferably be such, as to provide a suitable searching pattern for example, a downwardly expanding helix to enhance the probability that the torpedo upon being launched will sooner or later be oriented toward a target. In the event that the torpedo becomes so oriented and receives an echo which produces a doppler enabling pulse, the transfer relay **46** will operate and the acoustic control system will guide the torpedo toward the target under the control of the circuits operating in the manner set forth.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. For example, the slide bars can readily be replaced with a U-shaped armature pivoted at the bight of the U and moved from one side to the other by a solenoid control against the tension of a centering spring. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed as new and desired to be secured by Letters Patent of the United States of America is:

1. In a target-locating system, in combination: transmitter means for generating and projecting target-search radiant energy of substantially fixed frequency into a region which may encompass a moving target; a receiver, including transducer means having a directional response characteristic extending along a reference axis, for translating resultant reflected radiant energy to a single channel signal and to multi-channel signals, each of said single-channel and multi-channel signals comprising a spurious background component at a first frequency and, when a target is encountered by said target-search radiant energy, further comprising a target-echo at a second frequency differing from said first frequency by a Doppler-shift corresponding to the velocity of said target, the target-echoes in the multi-channel signals having relative characteristics corresponding to departure of target-direction from said reference axis; a first circuit comprising means for converting said single-channel signal to a heterodyned signal, and discriminator means having a characteristic center-frequency equal to the resultant heterodyned first frequency of said spurious component, and operating to convert the resultant heterodyned target-echo to an enabling voltage of magnitude corresponding to said Doppler-shift; and a second circuit, controlled by said enabling voltage to be operative only in time-coincidence therewith and when it exceeds a predetermined threshold magnitude, for deriving, from coincident target-echoes in said multi-channel signals, output signals having polarity corresponding to the sense of said departure of target direction.

2. In a target-locating system, in combination: transmitter means for generating and projecting target-search radiant energy pulses, of substantially fixed frequency and at repetitive instants separated by listening periods, into a region which may encompass a moving target, said pulses being of short duration relative to said listening periods; a receiver, including transducer means having a directional response characteristic extending along a reference axis, for translating resultant reflected radiant energy to a single-channel signal and to multi-channel signals, each of said single-channel and multi-channel signals comprising a spurious background component at a first frequency and, in each listening period wherein a target is encountered by a search-pulse, further comprising a discrete pulse-echo at a second frequency differing from said first frequency by a Doppler-shift corresponding to the velocity of said target, the pulse-echoes in the multi-channel signals having relative characteristics corresponding to departure of target direction from said reference axis; a first circuit comprising means for converting said single-channel signal to a heterodyned signal, and discriminator means having a characteristic center-frequency equal to the resultant heterodyned first frequency of said spurious component, and operating to convert the resultant heterodyned pulse-echo to an enabling pulse of magnitude corresponding to said Doppler-shift; and a second circuit, controlled by said enabling pulse to be operative only in time-coincidence with said pulse-echoes and when it exceeds a predetermined threshold magnitude, for deriving, from coincident pulse-echoes in said multi-channel signals, output signals having polarity corresponding to the sense of said departure of target direction.

3. In a target-locating system, in combination: transmitter means for generating and projecting target-search acoustic energy pulses, of substantially fixed frequency and at repetitive instants separated by listening periods, into an underwater region which may encompass a moving target, said pulses being of short duration relative to said listening periods; a receiver, including transducer means having a directional response characteristic extending along a reference axis, for translating resultant reflected acoustic energy to a single-channel signal and to multi-channel signals, each of said single-channel and multi-channel signals comprising reverberation at a first frequency and, in each listening period wherein a target is encountered by a search-pulse, further comprising a discrete pulse-echo at a second frequency differing from said first frequency by a Doppler-shift corresponding to the velocity of said target, the pulse-echoes in the multi-channel signals having relative characteristics corresponding to departure of target direction from said reference axis; a first circuit comprising means for converting said single-channel signal to a heterodyned signal, and discriminator means having a characteristic center-frequency equal to the resultant heterodyned first frequency of said reverberation, and operating to convert the resultant heterodyned pulse-echo to an enabling pulse of magnitude corresponding to said Doppler-shift; and a second circuit, controlled by said enabling pulse to be operative only in time-coincidence with said pulse-echoes and when it exceeds a predetermined threshold magnitude, for deriving, from coincident pulse-echoes in said multi-channel signals, output signals having polarity corresponding to the sense of said departure of target direction.

4. In a target-locating system, in combination: trans-

mitter means for generating and projecting target-search acoustic energy pulses, of substantially fixed frequency and at repetitive instants separated by listening periods, into an underwater region which may encompass a moving target, said pulses being of short duration relative to said listening periods; a receiver, including transducer means having a directional response characteristic extending along a reference axis, for translating resultant reflected acoustic energy to a first single-channel signal and to multi-channel signals, each of said first single-channel and multi-channel signals comprising reverberations at a first frequency and, in each listening period wherein a target is encountered by a search-pulse, further comprising a discrete pulse-echo at a second frequency differing from said first frequency by a Doppler-shift corresponding to the velocity of said target, the pulse-echo in the multi-channel signals having relative characteristics corresponding to departure of target direction from said reference axis; means for converting said multi-channel signals to a second single-channel signal wherein the pulse echo carries target direction information; means for converting said first single-channel signal to a heterodyned signal; common amplifier means for said heterodyned signal and said second single-channel signal; a first circuit including discriminator means having a characteristic center-frequency equal to the heterodyned first frequency of said reverberation, and operating upon the amplified heterodyned signal to convert the pulse-echo therein to an enabling pulse of magnitude corresponding to said Doppler-shift; and a second circuit, controlled by said enabling pulse to be operative only in time-coincidence with said pulse-echo and when said pulse exceeds a predetermined threshold magnitude corresponding to a predetermined Doppler-shift, for deriving, from the coincident pulse-echo in said second single-channel signal, output signals having polarity corresponding to the sense of said departure of target direction.

5. In a combination as defined in claim 4, wherein the intensity of said reverberation in each listening period is initially high immediately following transmission of a search pulse and decreases substantially in accordance with an exponentially-decaying amplitude curve, automatic control means for increasing the gain of said common amplifier means, as said reverberation intensity decreases during each listening period, to a varying maximum value consistent with maintaining the level of amplified reverberation below a threshold value which would result in spurious enabling pulses.

6. In a missile, in combination: transmitter means for generating and projecting target-search radiant energy of substantially fixed frequency into a region which may encompass a moving target; a receiver, including transducer means having a directional response characteristic extending along a reference axis, for translating resultant reflected radiant energy to a single-channel signal and to multi-channel signals, each of said single-channel and multi-channel signals comprising a spurious background component at a first frequency and, when a target is encountered by said target-search radiant energy, further comprising a target-echo at a second frequency differing from said first frequency by a Doppler-shift corresponding to the velocity of said target, the target-echoes in the multi-channel signals having relative characteristics corresponding to departure of target direction from said reference axis; a first circuit comprising means for converting said single-channel signal to a heterodyned signal, and discriminator means having a characteristic center-frequency equal to the resultant heterodyned first frequency of said spurious component, and operating to convert the resultant heterodyned target-echo to an enabling voltage of magnitude corresponding to said Doppler-shift; a second circuit, controlled by said enabling voltage to be operative only in time-coincidence therewith and when it exceeds a predetermined theshold magnitude, for deriving, from coincident target-echoes in said multi-channel signals, output signals having polarity corresponding to the sense of said departure of target direction; and missile steering gear responsive to said output signals to effect homing action of said missile toward said target.

7. In a missile, in combination: transmitter means for generating and projecting target-search radiant energy pulses, of substantially fixed frequency and at repetitive instants separated by listening periods, into a region which may encompass a moving target, said pulses being of short duration relative to said listening periods; a receiver, including transducer means having a directional response characteristic extending along a reference axis, for translating resultant reflected radiant energy to a single-channel signal and to multi-channel signals, each of said single-channel and multi-channel signals comprising a spurious background component at a first frequency and, in each listening period wherein a target is encountered by a search-pulse, further comprising a discrete pulse-echo at a second frequency differing from said first frequency by a Doppler-shift corresponding to the velocity of said target, the pulse-echoes in the multi-channel signals having relative characteristics corresponding to departure of target direction from said reference axis; a first circuit comprising means for converting said single-channel signal to a heterodyned signal, and discriminator means having a characteristic center-frequency equal to the resultant heterodyned first frequency of said spurious component, and operating to convert the resultant heterodyned pulse-echo to an enabling pulse of magnitude corresponding to said Doppler-shift; a second circuit, controlled by said enabling pulse to be operative only in time-coincidence with said pulse-echoes and when it exceeds a predetermined threshold magnitude, for deriving, from coincident pulse-echoes in said multi-channel signals, output signals having polarity corresponding to the sense of said departure of target direction; and missile steering gear responsive to said output signals to effect homing action of said missile toward said target.

8. In a search and homing torpedo, in combination: transmitter means for generating and projecting target-search acoustic energy pulses, of substantially fixed frequency and at repetitive instants separated by listening periods, into an underwater region which may encompass a moving target, said pulses being of short duration relative to said listening periods; a receiver, including transducer means having a directional response characteristic extending along a reference axis, for translating resultant reflected acoustic energy to a single-channel signal and to multi-channel signals, each of said single-channel and multi-channel signals comprising reverberation at a first frequency and, in each listening period wherein a target is encountered by a search-pulse, further comprising a discrete pulse-echo at a second frequency differing from said first frequency by a Doppler-shift corresponding to the velocity of said target, the pulse-echoes in the multi-channel signals having relative characteristics corresponding to departure of target direction from said reference axis; a first circuit comprising means for converting said single-channel signal to a heterodyned signal, and discriminator means having a characteristic center-frequency equal to the resultant heterodyned first frequency of said reverberation, and operating to convert the resultant heterodyned pulse-echo to an enabling pulse of magnitude corresponding to said Doppler-shift; a second circuit, controlled by said enabling pulse to be operative only in time-coincidence with said pulse-echoes and when it exceeds a predetermined threshold magnitude, for deriving, from coincident pulse-echoes in said multi-channel signals, output signals having polarity corresponding to the sense of said departure of target direction; and torpedo steering gear responsive to said output signals to effect homing action of said torpedo toward said target.

9. In a search and homing torpedo, in combination: transmitter means for generating and projecting target-search acoustitc energy pulses, of substantially fixed fre-

quency and at repetitive instants separated by listening periods, into an underwater region which may encompass a moving target, said pulses being of short duration relative to said listening periods; a receiver, including transducer means having a directional response characteristic extending along a reference axis, for translating resultant reflected acoustic energy to a first single-channel signal and to multi-channel signals, each of said first single-channel and multi-channel signals comprising reverberation at a first frequency and, in each listening period wherein a target is encountered by a search-pulse, further comprising a discrete pulse-echo at a second frequency differing from said first frequency by a Doppler-shift corresponding to the velocity of said target, the pulse-echo in the multi-channel signals having relative characteristics corresponding to departure of target direction from said reference axis; means for converting said multi-channel signals to a second single-channel signal wherein the pulse echo carries target direction information; means for converting said first single-channel signal to a heterodyned signal; common amplifier means for said heterodyned signal and said second single-channel signal; a first circuit including discriminator means having a characteristic center-frequency equal to the heterodyned first frequency of said reverberation, and operating upon the amplified heterodyned signal to convert the pulse-echo therein to an enabling pulse of magnitude corresponding to said Doppler-shift; a second circuit, controlled by said enabling pulse to be operative only in time-coincidence with said pulse-echo and when said pulse exceeds a predetermined threshold magnitude corresponding to a predetermined Doppler-shift, for deriving, from the coincident pulse-echo in said second single-channel signal, output signals having polarity corresponding to the sense of said departure of target direction; and torpedo steering gear responsive to said output signals to effect homing action of said torpedo toward said target.

10. In a search and homing torpedo combination as defined in claim 9, wherein the intensity of said reverberation in each listening period is initially high immediately following transmission of a search pulse and decreases substantially in accordance with an exponentially-decaying amplitude curve, automatic control means for increasing the gain of said common amplifier means, as said reverberation intensity decreases during each listening period, to a varying maximum value consistent with maintaining the level of amplified reverberation below a threshold value which would result in spurious enabling pulses.

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