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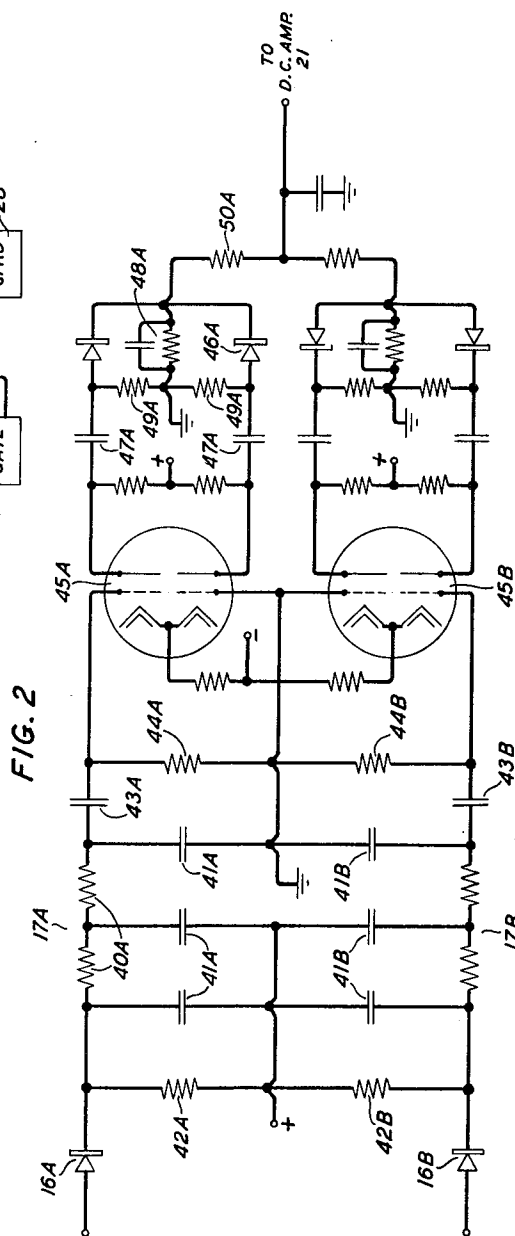
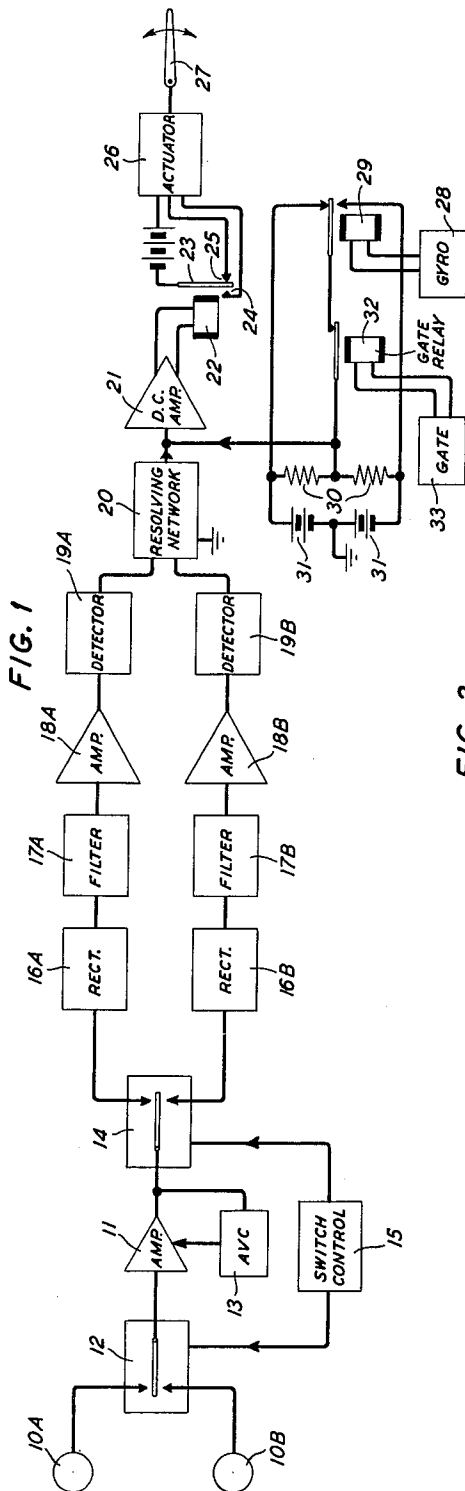
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3,054,370

TORPEDO STEERING SYSTEM

Filed Feb. 18, 1947

2 Sheets-Sheet 1



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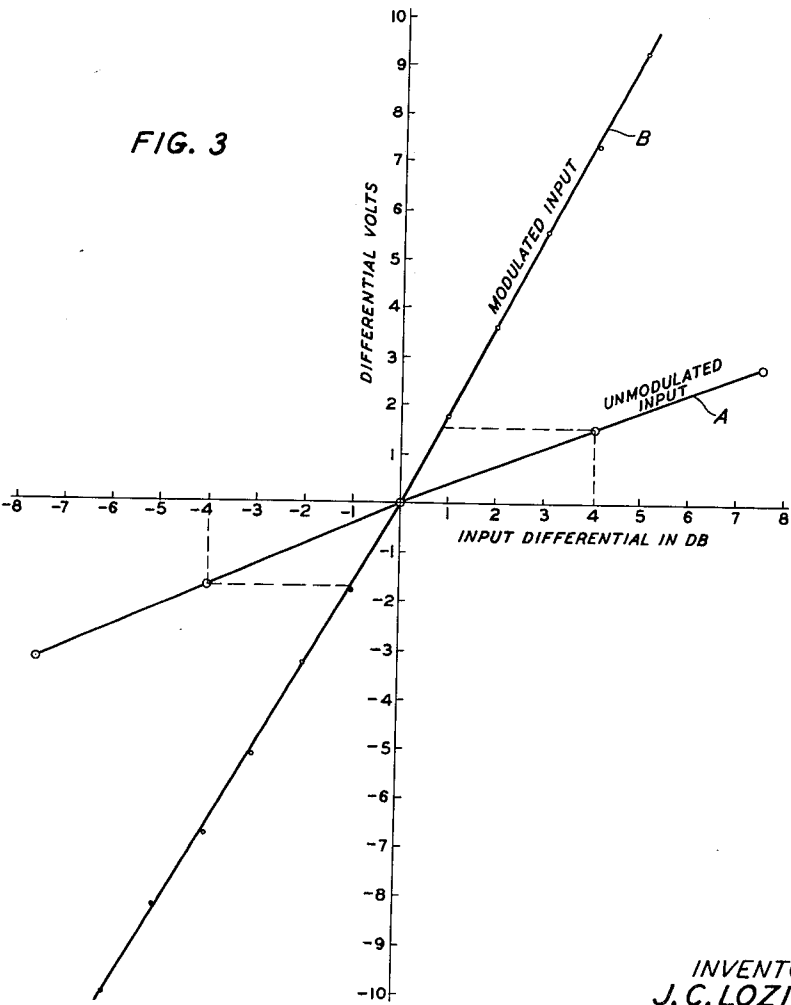
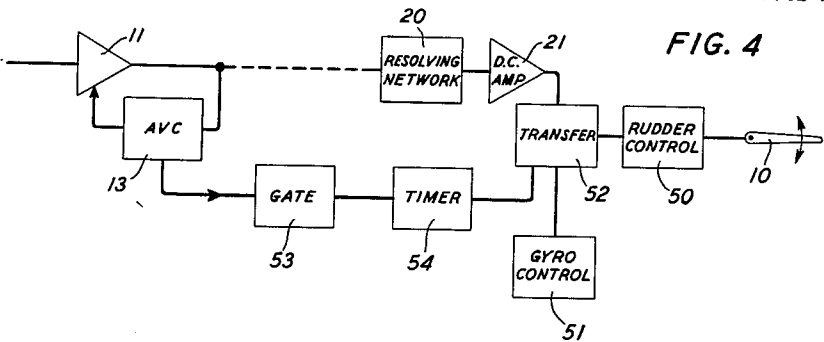
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2 Sheets-Sheet 2



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TORPEDO STEERING SYSTEM

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6 Claims. (Cl. 114-23)

This invention relates to signal translating systems and more particularly to steering control systems for torpedoes of the general type disclosed in the application Serial No. 600,905, filed June 22, 1945, of Charles F. Wiebusch, now Patent Number 3,003,449.

In a torpedo having a control system of this type, at and immediately following launching of the torpedo the rudder is under control of a gyroscope element and is actuated to maintain the torpedo upon a preset course. Subsequently, the rudder is controlled either by the gyroscope element and a signal translating system in combination or by such system alone, the system being responsive to underwater signals and effective to convert such signals emanating from a target and received at hydrophones upon the torpedo into a rudder control signal of amplitude and polarity determined by the bearing of the target relative to the torpedo.

It is eminently advantageous that the rudder be transferred from gyroscope to target signal or combined gyroscope and target signal control at as great a range as possible between torpedo and target. A limiting factor upon this range is the torpedo self noise, that is noise due to, for example, the torpedo propulsion mechanism and passage of the torpedo through the water. Such noise, in the form of underwater signals, is received at the hydrophones and may be converted into a rudder control signal. In order to prevent false steering of the torpedo upon such self noise, it has been necessary heretofore to design the steering system so that transfer of the rudder from gyroscope to combined target signal-gyroscope or target signal control can occur only when the target signal level at the hydrophones is substantially greater than the probable self noise level. This entails or represents a loss in target signal control range inasmuch as the signal control system is capable of effecting steering at substantially lower signal levels.

One object of this invention is to increase the target signal control range of torpedoes adapted to be guided in accordance with such signals.

More specifically, one object of this invention is to increase the target to torpedo range for a torpedo having a rudder subject to both gyroscope and target signal control, at which the rudder can be safely transferred from gyroscope to combined gyroscope and target signal or solely target signal control.

In one illustrative embodiment of this invention, a torpedo steering control system comprises a pair of signal channels each having a hydrophone coupled to its input end, the two hydrophones being mounted so that the relation of the outputs thereof is determined, in polarity and amplitude, by the bearing relative to the torpedo of the source from which the underwater signals received by the hydrophones emanate. The hydrophone outputs are resolved in combination into a difference signal of polarity determined by and amplitude proportional to the bearing noted. The system includes also a rudder actuating and control element for effecting deflection of the rudder in accordance with the polarity and amplitude of the signal applied thereto. Both the difference signal and a signal of preassigned magnitude and of polarity determined by the direction of departure of the torpedo from the gyroscope course are applied to the control element.

In one embodiment, the two signals, i.e. difference and

gyroscope, are applied in combination to the control element so that the point at which the rudder is transferred from gyroscope to combined gyroscope and underwater signal control is determined by the amplitude of the gyroscope signal.

As has been indicated heretofore, the hydrophones receive underwater signals due to the target and also signals due to self noise. The two types of signals, although generally including the same band of component frequencies, are different in character. Specifically, the signals due to the target are modulated at low frequencies, i.e., at frequencies associated with the propeller blades and shaft of the target, whereas the signals due to self noise are unmodulated. As will be brought out presently, the power in the modulated signals after detection is concentrated primarily at the modulating frequencies whereas the power in the unmodulated signal is spread on the average over a wide range of frequencies.

In accordance with one feature of this invention, the signal channels are constructed and arranged to pass and detect only the modulating frequencies whereby the target signals produce a greater difference signal than the self noise. Consequently, a high ratio of signal to noise is obtained. Thus, the gyroscope control signal may be made of relatively small amplitude, protection against false steering on self noise is afforded and transfer from gyroscope to combined gyroscope and target signal control may be effected at a long target to torpedo range.

The invention and the above-noted and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing, in which:

FIG. 1 is a circuit diagram, mainly in block form, of a torpedo steering system illustrative of one embodiment of this invention;

FIG. 2 is a diagram showing details of a portion of the system illustrated in FIG. 1.

FIG. 3 is a graph illustrating the detector outputs for both modulated and unmodulated signals; and

FIG. 4 is a diagram in block form illustrating another embodiment of this invention.

Referring now to the drawing, the steering system therein illustrated in FIG. 1 comprises a pair of hydrophones 10A and 10B, for example of the construction disclosed in the application Serial No. 491,797, filed June 22, 1943, of John C. Steinberg, which, as disclosed in that application, are mounted upon the torpedo on opposite sides of the longitudinal axis thereof so that the relative response of the two hydrophones is a measure of the bearing relative to this axis of the source from which underwater signals received by the hydrophones emanate. The two hydrophones are connected in alternation to a high frequency amplifier 11 by a switch 12, the amplifier being provided with automatic gain control 13. The amplifier output is supplied in alternation, over a second switch 14, to two substantially identical signal channels. The two switches are operated in synchronism by a switch control 15. A suitable construction and arrangement of the switches 12 and 14 and amplifier 11 is disclosed in the application Serial No. 491,795, filed June 22, 1943, of Donald D. Robertson. The association of elements is such that the two hydrophones are connected in alternation, through the amplifier 11, each to a respective signal channel.

In the drawing, corresponding elements of the two channels are designated by the same reference numeral plus the letter, A or B, of the respective hydrophone. Each channel comprises a rectifier 16, a low-pass filter 17, a low frequency amplifier 18 and a detector 19, connected serially in the order mentioned. The outputs of the two detectors 19 are supplied to a resolving network 20

wherein the outputs are converted into a direct current potential of sign determined by and amplitude proportional to the relative magnitudes of these outputs.

This potential is applied to the input of a direct current amplifier 21 which controls a relay 22 to operate or release in accordance with the polarity of the effective input potential to this amplifier. The relay, which has an armature 23 and front and back contacts 24 and 25, controls an actuator 26, for example a reversible motor, for a rudder 27, to effect deflection of the rudder in one direction or the other in accordance with the polarity of the effective input signal to the amplifier 21.

Associated with the input circuit for the direct current amplifier 21 is a gyroscope control comprising a gyroscope 28 which controls a relay 29 in accordance with the direction of departure of the torpedo from a preset course. The relay 29 has its armature and contacts connected to equal resistors 30 and equal sources such as batteries 31, as shown, the connection from the armature to the resistors being over the armature and contact of a gate relay 32. As is apparent, a voltage or signal of polarity dependent upon the condition of the relay 29 is impressed upon the input circuit of the amplifier 21. The polarities involved are made such that the rudder deflection produced in accordance with the gyroscope signal is in the direction to return the torpedo to the course for which the gyroscope is set.

The gate relay 32 is under control of a gate 33 which may be of the type disclosed in the application Serial No. 600,905, filed June 22, 1945, of Charles F. Wiebusch, now Patent Number 3,003,449. Alternatively, it may be of the amplitude type, i.e., effective to cause operation of the relay 32 when the signal level at the hydrophones 10 reaches a preassigned value.

The general operation of the system is as follows. When the torpedo is launched, the amplifier 21 is under control of the gyroscope so that the rudder 27 is deflected accordingly to maintain the torpedo on the course for which the gyroscope is set. When the torpedo proceeds toward the target, at some point in its path the signal or voltage produced at the resolving network 20 due to underwater signals received by the hydrophones 10 will be equal to or greater than the voltage applied to the amplifier 21 by the gyroscope control. Thus, as described in the application of Charles F. Wiebusch above identified, the torpedo proceeds under combined gyroscope and underwater signal control. As the torpedo approaches closer to the target, the target signal level at the hydrophones 10 increases and at a preassigned point, determined by the level for which the gate 33 is set, the gate relay 32 operates to effectively dissociate the gyroscope control from the amplifier 21. Thereafter, the torpedo proceeds to the target under target signal control alone.

It is eminently advantageous from the standpoint of success of attack that the torpedo to target range at which the output or control voltage at the resolving network 20 becomes equal to the gyroscope control voltage to be as great as possible. For any given underwater signal control circuit, this range is dependent upon the amplitude of the voltage applied to the amplifier 21 by the gyroscope control. The minimum value at which this voltage may be set is determined primarily by the torpedo self noise, e.g., noise due to its propeller and propulsion mechanism and its passage through the water. Such noise is received by the hydrophones and may result in an output voltage at the resolving network 20.

In order to prevent false steering as a result of such a voltage, it has been found necessary heretofore to set the gyroscope control voltage relatively high, sufficiently so that equality of this voltage and the output voltage from the network 20 obtains only when the target signal level at the hydrophones is above that of the self noise. This represents a substantial loss in target signal control range inasmuch as the underwater signal control circuit is ca-

pable of effecting steering of the torpedo in response to signals of level at the hydrophones 10 considerably below the level of combined target signal and self noise for which the gyroscope control is set to prevent false steering on self noise.

In accordance with one feature of this invention, such loss in target signal control range is substantially reduced.

The principles involved will be understood from the following considerations. Any relatively narrow band of high frequency noise has low frequency fluctuations in the amplitude of its envelope. In the case of torpedo self noise, such fluctuations represent the beat or difference signals between various frequencies in the band. Noise emanating from a ship is modulated at definite frequencies, specifically, it has been found, at frequencies associated with the ship's propeller, i.e., the blade and shaft frequencies.

When such modulated noise is rectified to produce a signal of envelope frequency, the signal power is concentrated primarily in a few discrete frequencies. However, when an unmodulated noise, such as torpedo self noise, is rectified similarly, the power in the signal obtained is spread on the average over the frequency band from zero to the highest beat frequency.

As is apparent, the hydrophones 10 receive both modulated signals, i.e., high frequency target signals modulated at the target propeller frequency, and unmodulated signals, i.e., signals due to torpedo self noise. Because of the difference in the power distribution for the two types of signals as pointed out above, the effective signal to self noise ratio in the signal channel outputs may be substantially increased by restricting the comparison to a part of the frequency spectrum that includes discrete modulation frequencies, specifically frequencies associated with the propellers of ships to be attacked by the torpedo.

In a specific and illustrative system, the hydrophones 10 may be designed to be resonant at 24 kilocycles and the amplifier 11 may be designed to have a preassigned bandwidth center about 24 kilocycles. The filters 17 may be designed to pass only low frequencies in the band between 2 and 20 cycles inclusive. The low frequency signals, after amplification in the amplifiers 18 and detection at 19 are combined in the resolving network 20 to produce a difference signal proportional to the difference in the inputs to the two hydrophones 10.

The performance of the system and the increase in target signal range for the torpedo obtained by use of envelope detection is illustrated in FIG. 3. In this figure, the output of the resolving network is plotted as ordinates against difference in inputs to the two hydrophones for signals from the same noise source, the amplifier 11 translating a band of 1500 cycles centered about 24 kilocycles. The line A shows the relation for an input differential of unmodulated high frequency noise; the line B shows the relation for an input differential of high frequency noise modulated sinusoidally at 6 cycles per second. It is apparent from FIG. 3 that the difference signal obtained from the network 20 for any given difference in inputs to the hydrophones is of the order of four times as great for the case of the modulated input than for the unmodulated input.

Consideration of an example will demonstrate the increase in target signal control range which may be realized by the use of envelope detection in the system. Assume that the voltage applied to the input of the amplifier 21 by the gyroscope control circuit is 1.7 volts. It will be noted from the line A in FIG. 3 that in order that underwater signals of unmodulated noise received at the hydrophones could produce an output voltage at the resolving network 20 equal to the gyroscope control voltage, the input differential at the hydrophones would need be 4 decibels. However, as is apparent from line B, for modulated noise, e.g., target signals modulated at target propeller frequencies, an input differential at the hydro-

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phones of only 1 decibel is adequate to produce at the resolving network an output voltage equal to the gyroscope control voltage.

Thus, it is apparent that by restricting the frequencies which can be passed to the detectors 19, to those associated with the propellers of target ships, a substantial increase in target signal to self noise ratio is obtained. This means that the gyroscope control voltage can be set at a lower value to afford protection against false steering on torpedo self noise, so that, consequently, a substantial increase in target signal control range is realized.

Details of a typical system are illustrated in FIG. 2. The rectifiers 16 may be of the copper oxide disc type and, as shown, are arranged to have the same polarity in order to prevent dissymmetry in the envelope modulation from producing a differential signal. Each of the filters 17 comprises a two section low-pass portion, including series resistors 40 and shunt capacitances 41, connected to input resistors 42, and a single section high-pass portion including a series capacitance 43, and a shunt resistor 44. The two portions constitute a band pass filter, the parameters of the elements thereof being correlated, in ways known in the art, to transmit frequencies within a preassigned band, e.g. from 2 to 20 cycles.

Each of the amplifiers 18 comprises a twin unit electron discharge device 45 of the high vacuum type arranged for push-pull operation as shown so that an output balanced to ground is realized and effective full wave rectification is readily obtainable. The amplifier outputs are supplied to respective rectifiers 46, which may be of the copper oxide disc type, over suitable condensers 47, the rectifiers being connected in parallel with respective resistor-condenser combinations 48 to which they are connected by equal resistors 49. Thus, the outputs of the two amplifiers are detected to produce two direct current voltages which are combined in difference relation by way of resistors 50 to provide a control signal applied to the input of amplifier 21, of polarity determined by and amplitude proportional to the relative inputs to the rectifiers 16 and, hence, to the relative inputs to the hydrophones 10. The relative inputs to the hydrophones 10, when a substantial target signal level obtains at the hydrophones, are determined by and are a measure of the bearing of the target relative to the torpedo.

As has been pointed out heretofore, the high frequency amplifier 11 is designed to amplify a band of frequencies centered about that to which the hydrophones are resonant. Advantageously this band is made very large relative to the pass band of the filters 17. In general, the greater the ratio of the two bandwidths, the greater is the improvement in detection of a modulated signal over that of an unmodulated one, so that as this ratio is increased, the steering system is operable to effect correct steering on lower signal-to-noise ratios, i.e., on lower ratios of modulated noise to unmodulated noise in the band of frequencies translated by the amplifier 11. For example, if the band passed by the amplifier 11 is increased by a factor of 10, say from 1500 to 15,000 cycles, an improvement of the order of 10 decibels in detection of the modulated signal over an unmodulated one may be realized.

The invention may be embodied also, as illustrated in FIG. 4, in steering systems, such as disclosed in the application Serial No. 545,835, filed July 20, 1944, of Alton C. Dickieson, now Patent Number 3,004,508, wherein transfer of the rudder from gyroscope to target signal control is effected by an amplitude type gate. As illustrated in FIG. 4, the rudder control 50, which may comprise the relay 22 and actuator 26 shown in FIG. 1, is arranged to be coupled to either the gyroscope control 51 or the direct current amplifier 21 by a transfer element 52. The gyroscope control 51 is such that it effects operation or release of the relay 22 in accordance with the direction of departure of the torpedo from the gyro-

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scope course, so that the rudder 27 is deflected to return the torpedo to this course.

The transfer element is connected to the automatic volume control circuit 13 by way of a gate 53 and a timer 54, the timer being such that it holds the connection open until the torpedo, after launching, has traveled away from the launching vessel a distance sufficient to place it beyond the effective underwater signal field of the launching vessel. The gate 53 normally holds this connection open until a voltage of preassigned amplitude appears in the AVC circuit. The voltage in this circuit is proportional, of course, to the signal level at the hydrophones 10.

In the system illustrated in FIG. 4, the portions of the circuit between the hydrophones 10 and amplifier 11 and between this amplifier and the resolving network 20 are identical with the corresponding portions of the system illustrated in FIG. 1 and have been omitted from FIG. 4 to simplify the drawing.

When a torpedo having a steering system of the construction illustrated in FIG. 4 is launched, the gyroscope control 51 is associated with the rudder control 50 by way of the transfer 52 and the direct current amplifier 21 is dissociated from the rudder control. Thus, the torpedo proceeds under gyroscope control. When it reaches a point beyond the effective underwater signal field of the launching vessel the timer 54 operates to enable the gate circuit. When, after the timer has operated, the signal level at the hydrophones 10 reaches a preassigned magnitude, the gate 53 operates, whereby the transfer 52 operates to dissociate the gyroscope control 51 from the rudder control 50 and to associate the amplifier 21 with the control 50. Thereafter the torpedo proceeds to the target under target signal control.

Because of the restriction, by the filters 17, of the frequencies which are resolved into the difference control signal at the resolving network 20, and in view of the difference in character of the target signals and the torpedo self noise pointed out heretofore, it will be appreciated that the gate 53 may be set to operate for a relatively low signal level at the hydrophones 10 and still afford protection against false steering of the torpedo by self noise. Thus, the range at which the rudder is transferred from gyroscope to target signal control is increased relative to that which it would be if in the signal translating channels a wide band of frequencies were passed and detected instead of only the preassigned modulation frequencies, e.g. between 2 and 20 cycles.

Although specific embodiments of the invention have been shown and described, it will be understood that they are but illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. A torpedo steering system comprising a rudder, control means for effecting deflection of said rudder in one or the opposite direction in accordance with the polarity of signals impressed upon the control means, means for impressing upon said control means a signal of preassigned magnitude and of polarity determined by the direction of departure of the torpedo from a prescribed course, and means responsive to underwater signals at the torpedo for impressing upon said control means a signal of amplitude proportional to and polarity determined by the effective bearing relative to the torpedo of the source of the underwater signals, said last-mentioned means comprising a pair of hydrophones mounted on the torpedo, responsive to high frequency underwater signals and arranged so that the relative response thereof is a function of the bearing relative to the torpedo of the source of signals received by the hydrophones, a pair of similar signal channels for each of which a respective hydrophone constitutes the input element, each of said channels including a rectifier, a filter connected to the output of the rectifier and having a pass band embracing only a prescribed limited range of low frequencies and a detec-

tor energized in accordance with the output of the filter, means for resolving the outputs of the two detectors into a difference signal, and means for applying said difference signal to said control means.

2. A signal translating system comprising a pair of high frequency signal translating units arranged so that the relative output thereof for signals from a common source is determined by the bearing of the source relative to the units, a pair of similar signal translating channels, means for coupling each of said units to the input end of a respective channel, each of said channels comprising a rectifier energized in accordance with the output of the respective translating unit, a filter energized in accordance with the rectifier output and having a pass band embracing only a preassigned restricted range of low frequencies and detector means energized in accordance with the filter output, means for resolving the outputs of the detector means in said two channels into a difference signal, and utilization means controlled in accordance with said difference signal.

3. An underwater signal translating system comprising a pair of hydrophones responsive to supersonic signals and arranged so that the relative response thereof is a function of the bearing relative thereto of the source of signals received thereby, a pair of similar signal translating channels, means for coupling each hydrophone to the input of a respective channel, each of said channels including a rectifier energized in accordance with the output of the respective hydrophone, a filter coupled to the output of the rectifier and having a pass band embracing only a limited range of low frequencies and a detector energized in accordance with the output of the filter, means for resolving the outputs of the detectors in the two channels into a difference signal, and operating means controlled in accordance with said difference signal.

4. A steering system for a moving body, comprising a steering member, control means for effecting operation of said member to steer the body in one or the opposite direction in accordance with the polarity of signals applied to the control means, gyroscope controlled means for producing a first control signal of preassigned amplitude and of polarity determined by the direction of departure of the body from a prescribed course, signal translating means responsive to signals within a range of high frequencies for producing a second control signal of amplitude and polarity determined by the bearing relative to the body of the source of signals received by the signal translating means, and means for applying said first and second control signals to said control means, said signal translating means comprising a pair of signal translating units mounted on the body and arranged so that the relative response thereof is determined by the bearing relative to the body of signals received by the units, a pair of signal channels for each of which a respective

unit constitutes the input element, each of said channels including means for detecting only envelope modulation frequencies of said high frequencies, within a limited range of low frequencies, and means for combining the outputs of the detecting means in the two channels in difference relation to produce said second control signal.

5. A signal translating system comprising a pair of signal translating units arranged so that the relative response thereof is a function of the bearing relative thereto of signals received thereby, said units being capable of translating signals within a prescribed kilocycle range, a pair of similar signal channels for each of which a respective translating unit constitutes the input element, each of said channels comprising a rectifier, a filter, a push-pull low frequency amplifier and a detector serially connected in the order named, the rectifier in each channel being at the input end thereof and the two rectifiers being poled alike, the filter having a pass band embracing only a prescribed restricted range of low frequencies whereby only modulation frequencies within said restricted range are detected by said detectors, means for combining the outputs of the two detectors in difference relation to produce a resultant signal, and operating means energized in accordance with said resultant signal.

6. A torpedo steering system comprising a pair of hydrophones responsive to underwater signals of frequencies within a prescribed kilocycle range, said hydrophones being mounted on the torpedo so that the relative response thereof is a function in sign and magnitude of the bearing relative to the torpedo of signals received by the hydrophones, a pair of similar signal channels, means for coupling each hydrophone to the input end of a respective signal channel, each of said channels comprising a rectifier, a filter and a detector serially connected in the order named with the rectifier toward the input end of the channel, the rectifiers in the two channels being poled alike and the filter in each channel having a pass band between of the order of 2 and 20 cycles, means for combining the outputs of the detectors in the two channels in difference relation to produce a resultant signal, a rudder, control means for said rudder for effecting deflection thereof in accordance with the polarity of signals applied to the control means, and means for applying said resultant signal to said control means.

References Cited in the file of this patent

UNITED STATES PATENTS

1,121,563	Leon	Dec. 15, 1914
2,382,058	Hull	Aug. 14, 1945
2,434,278	Mason	Jan. 13, 1948
2,457,393	Muffly	Dec. 28, 1948

FOREIGN PATENTS

529,040	Germany	July 10, 1931
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