United States Patent

Haase et al.

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[54] REMOTE CONTROL METHODS AND SYSTEMS

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[52] **U.S. Cl.** .....**340/5 R**, 325/37, 340/16 C, 340/171 A, 343/225

[51] **Int. Cl.** **H04b 11/00**

[58] **Field of Search** .....340/2, 3 E, 5, 16 R, 171; 325/37, 44; 343/225–227

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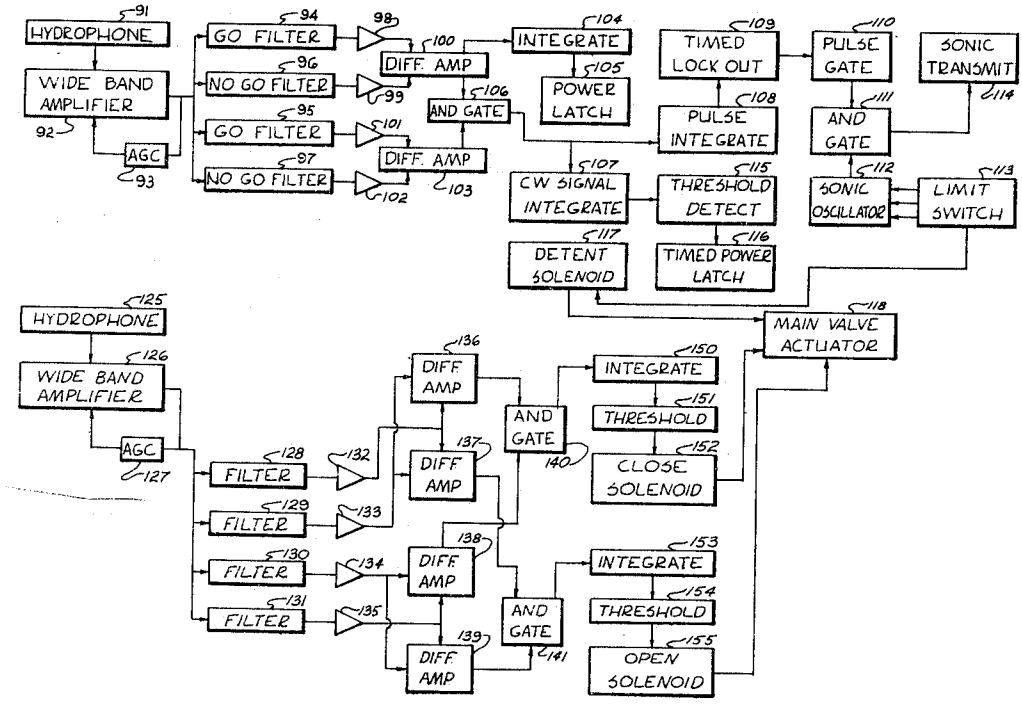
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[57] **ABSTRACT**

This invention relates to improvements in remote control systems and operating methods. The embodiment selected for illustration is arranged for actuation of a valve in a submerged pipeline. The system includes a controlling station comprising a transmitter and a receiver of sonic signals and it includes a controlled station submerged with the valve and comprised of a receiver and a transmitter. The controlling station is capable of sending arming, interrogation and control signals to the controlled station. The operating and interrogating codes employed in the system include at least two different frequency components and require that certain other frequency components be absent. The receiver of the control station is responsive to such codes to arm the receiver to receive an interrogation signal and an actuating command signal. It is effective upon receiving the interrogation signal to cause a response to be transmitted indicating the condition of the valve to be controlled and placing the system in condition to receive valve control instruction.

8 Claims, 4 Drawing Figures



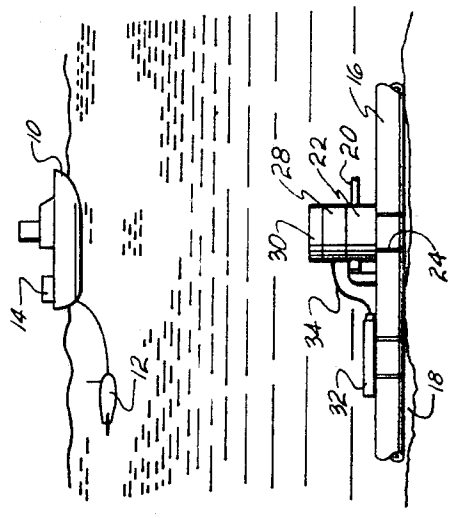


FIG. 1.

FIG. 2.

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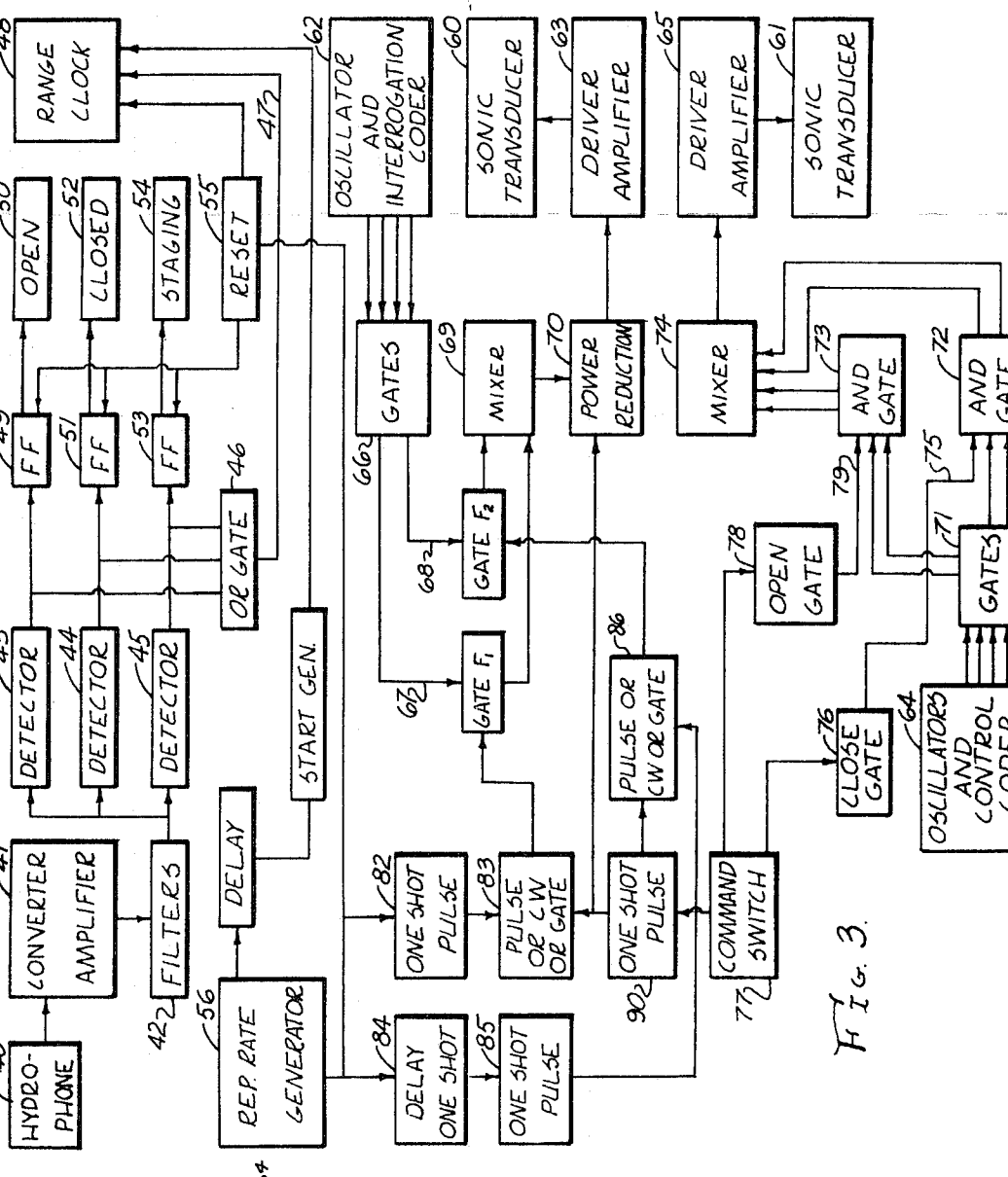


FIG. 3

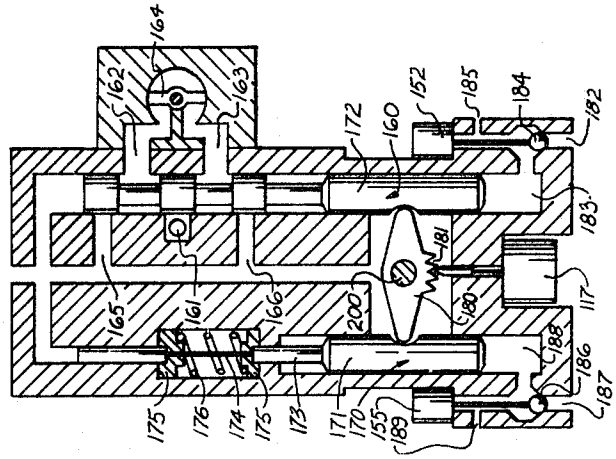


FIG. 4

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REMOTE CONTROL METHODS AND SYSTEMS

This invention relates to improvements in remote control systems to improved apparatus for such systems, and to improved methods of remote control.

The problem of controlling a remote apparatus is often complicated by the need to provide for conservation of power at the remote controlled station, by the need to provide security against unauthorized operation and, in certain instances, by the need to provide a means for locating the remote apparatus before it can be operated. One example of the latter is found in the remote operation of the valves of a submerged pipeline. There are a number of natural gas and petroleum lines which are submerged and which include valves located at substantial depths out of sight of land where location may be difficult. The invention is not limited to the remote control of such valves. Nonetheless, this application deals with a number of problems which are solved to advantage by the invention and the provision of a secure system for locating and controlling such valves is one of the objects of the invention. In a broader sense, an object of the invention is to provide an improved remote control system. Another object is to provide a remote control system incorporating features which make it secure against unauthorized or inadvertent operation. In this connection, it is an object of the invention to provide a system which will be secure against operation by frequency sweeping and pulsing apparatus.

In the invention energy is radiated from a controlling station to the controlled station. Alternating energy is employed and the energy may be electromagnetic or mechanical or sonic in form. The controlled apparatus is made responsive either to the duration or the frequency of the controlling signals or to both. Amplitude may be employed but is a less useful variable than frequency and duration of signal. In underwater control applications where control signals may be reflected a number of times, control codes based on on time and off time of signal segments may not be reliable. An object of the invention is to provide a remote control system which overcomes these difficulties and to provide a remote control system whose control codes are based upon combinations of frequency components. One object of the invention is to provide a remote control system which responds to signals incorporating selected frequency components and from which certain other frequency components are absent.

It is a feature of the invention that one code is employed to arm the controlled station and another code is employed, in the preferred embodiment, to command actuation of the apparatus to be controlled. One or both of those codes may incorporate as a security measure that the code signal incorporate components of given frequency and that it be free of components of another frequency. In this embodiment a third code is employed in searching for the remote, submerged apparatus and for interrogating that apparatus about its operating condition. It is also a feature of the invention that the several codes may include signal duration, particularly the duration of certain components of the signal, as elements of the code. The embodiment selected for illustration in the drawings employs signal duration as part of its codes such that a combination of frequency components and signal duration is made to command the controlled apparatus to vary the rate at which power is supplied to that apparatus. A related object is to provide a remote control system which is reliable and secure in its operation while minimizing the complexity and increasing the reliability of the system and its components.

The system selected for illustration is made specifically to locate an underwater apparatus, to interrogate that apparatus and have it respond with a signal indicating the status of the apparatus to be controlled, to become armed in preparation to obeying command signals upon receipt of a predefined coded signal, to obey coded commands to alter operating condition of the controlled apparatus, and to signal operating status following the command.

In the drawings:

FIG. 1 is a diagram of a submerged section of pipeline including a valve to be actuated, control apparatus for actuating that valve upon the receipt of sonic signals, controlling apparatus including a transmitter of sonic signals and a vessel for transporting the controlling portion of the system which together embody the inventions;

FIG. 2 is a block diagram of elements associated together to form the portion of the system that is submerged at the valve to be controlled;

FIG. 3 is a block diagram of elements which together form the controlling apparatus carried by the vessel of the FIG. 1; and

FIG. 4 is a schematic diagram of a preferred form of solenoid and gas pilot valve actuator arrangement employed in the invention.

Referring to FIG. 1 of the drawing, the system there shown comprises a transmitter of sonic interrogation signals, arming signals, and command signals, and a receiver of signals from a remote station to be controlled. In the embodiment of FIG. 1 the vessel **10** is shown towing a submerged sonic transducer and hydrophone assembly **12**. Transmitting apparatus in which those transmitted signals are generated and receiving apparatus in which signals received by the hydrophone are processed, is represented by the structure **14** carried by vessel **10**.

A section of a pipeline **16** is shown to lie on the ocean floor **18**. A branch line **20** communicates with the pipeline **16**. The branch line **20** includes a valve which is to be opened and closed remotely. The valve **22** is located in the lower section of a three-part housing that is strapped by straps **24** to the main line **16**. That housing also includes a receiver **28** and a transmitter **30**. Means are provided for supplying power to the transmitter and receiver. In certain applications of the invention that means may comprise apparatus to utilize potential energy stored in the material being transported in the pipeline. In the embodiment selected for illustration, that means comprises a battery pack **32** which is strapped to the main pipeline **16** through a power cable **34**.

The method of the invention may be practiced utilizing this arrangement of apparatus. In the method a first plurality of characteristic signals is sent from a first station for a period of time. A second plurality of characteristic signals is sent from the first station for a portion of that period of time. The first and second plurality of signals are received at a second station and if both the first and second plurality of signals is received, a third characteristic signal is sent. In this embodiment that third characteristic signal comprises a command signal resulting in actuation of the valve. In the preferred form of the method the second plurality of signals is received at the second station only after the first plurality of signals is received. In this embodiment that step is utilized to conserve power at the submerged station by disabling that portion of the receiver which receives, or responds to the second plurality of signals. In the preferred form of the method the steps previously described are preceded by the preliminary step of transmitting a characteristic interrogation signal from the first station and beginning to count time at the same time that signal is set. The interrogation signal is received at the second station and an answering signal is transmitted from the second station. The answering signal is received at the first station and when it is received the counting of time is terminated whereby to provide a measure of the distance from the first to the second stations. Moreover, in the preferred method of the invention the first station is made to transmit a fourth characteristic signal subsequent to issuing its first and second signals. In this embodiment that fourth signal is an interrogation signal interpreted at the second station as an instruction to return a signal, a fifth characteristic signal, indicative of the state or operating condition of the apparatus to be controlled. Such a step is included in the method together with the step of interpreting the fifth signal when received at the first station to identify the state of the condition. It will be apparent that this signalling method is applicable to remote control problems

other than the one shown and will be useful in sending instructions to a remote station in space or to a remote station on land, or to a remote station on the surface of the sea. A wide variety of apparatus is available to practice the several steps of the invention and some of them, particularly the generation and transmission of characteristic sonic signals, can be accomplished by hand.

A preferred form of apparatus to practice the methods is represented in FIGS. 2, 3, and 4. The several portions of the whole system there shown are advantageously employed although it is to be understood that any of these several sections may have alternative form. The shipborne apparatus is shown schematically in FIG. 3. That apparatus consists of a sonic signal receiver and a sonic signal transmitter. In the sonic signal receiver portion of FIG. 3, sonic signals reaching hydrophone 40 are converted into electrical signals which are supplied to a converter amplifier 41 corresponding generally to the first detector and intermediate frequency amplifier of a superheterodyne receiver. The amplified output signal is applied to a series of filters 42 which separate the amplifier output signals according to frequency. Signals of one frequency are supplied to a detector 43 whereas signals of another frequency are supplied to a detector 44. Signals of a third frequency are supplied to a detector 45. These detectors 43, 44, and 45 correspond to the second detector of a superheterodyne receiver and make it possible to identify any one of three frequencies in the received sonic signal. All three detectors have their output circuits connected to an OR-gate 46 and if the signal appears at the output of any detector the OR gate will apply a stop signal on output line 47 to a range clock 48. The output, if any, from detector 43 triggers a flip-flop 49 to send a signal to indicator 50 which in this application signifies that the valve to be controlled is in its open position. If a signal appears at the output of detector 44 then that signal will trigger a flip-flop 51 and cause it to send a signal to an indicator 52 which is lighted to indicate that the valve is closed. If an output signal appears at the output of detector 45 that signal will actuate flip-flop 53 to send a signal to a third indicator designated by the reference numeral 41 which lights to indicate that the valve is being operated or is "staging" from one operating condition to another. The flip-flops are reset as hereinafter described by a reset signal generator 55. The controlled station sends its sonic signals in response to interrogation signals sent from the transmitter portion of the apparatus depicted in FIG. 3. That transmitter includes a pulse generator 56 which generates pulses at a selected pulse repetition rate. It supplies the timing signal which control the sending of sonic signals from the transmitter and it determines the sequence and duration of those signals.

The transmitter includes two output sections called sonic transducers which provide a sonic signal output in response to an electrical signal input. One of the transducers is designated by reference numeral 60. The other of the sonic transducers or output elements is designated by reference numeral 61. The transmitter includes two groups of oscillators. The sonic signals generated in oscillator 62 are transmitted by the sonic transducer 60 after being amplified in driver-amplifier 63. Oscillators 64 supply signals to driver-amplifier 65 from whence they are applied to the sonic transducer 61. In the case of both sections of the transmitter, the oscillator signals are applied through a series of gates and a mixer to the driver-amplifier. Also, both of the oscillator units 62 and 64 are capable of generating more frequencies than may actually be used in a given control code. Block 62 also includes an interrogation coder which makes it possible to select frequencies to form a given code. Similarly, the block 64 represents a unit capable of generating more frequencies than are required for a given control code and a control coder is incorporated by which selected ones of the oscillators are made to supply an output and others are prevented from supplying an output. Interrogation signals from oscillator and interrogation coder 62 are applied to a series of gates represented by block 66. In this embodiment two frequencies are used to form the interrogation signal. Accordingly, output from one oscillator is applied by line 67 to a gate F1 and the output from another oscillator is applied by a line 68 to a gate F2. The output of these two gates is applied to a mixer 69. The mixer output is applied to the driver-amplifier 63 through a means for reducing the power output in the form of an attenuator or power reduction circuit 70.

In the other section of the controlling station transmitter, output from the oscillator and control coder 64 is applied to a series of gates 71. In this embodiment four oscillators are employed and four signals, each a different frequency, are applied to the gate 71. Two of those signals are applied to an AND-gate 72 and the other signals are applied to an AND-gate 73. The two signals applied to AND-gate 72 are applied to a mixer 74 and thence to driver-amplifier 65. If a signal is applied to AND-gate 72 by a line 75 from a gate 76 labeled "-CLOSE GATE." A command switch 76 applies a signal to the closed gate 76 in one of its positions and it applies a signal to a gate 78 labeled "OPEN GATE" in its other position. When the signal is applied to the open gate 78 that gate applies a signal by line 79 to AND-gate 73. In that event, it is the two signals applied to AND-gate 73 rather than the two oscillator signals applied to AND-gate 72 which are applied to mixer 74. The two signals applied to AND-gate 73 have frequencies different than the two signals applied to AND-gate 72. Means are provided at the controlled station to receive signals transmitted by sonic transducer 61.

If the signals passing through gate 73 are transmitted by sonic transducer 61 they will be interpreted at the controlled station as an instruction to open the valve 22. If instead the signals applied to sonic transducer 61 are those which pass through gate 72, then the signal received at the control station will be interpreted as an instruction to close the valve 22. In this embodiment the command switch 77 is manually operated to issue an instruction which ultimately becomes a command to open the valve or to close it.

Prior to operating the valve however, it is advantageous to know whether the valve is open or closed. The other section of the controlling station transmitter is included to permit interrogation of the controlled station, to arm it, to put it into condition to receive commands, and also to initiate range clock counting. The interrogation and arming signals are those sent by the sonic transducer 60 and are the signals that pass through gates F1 and F2.

In the system illustrated in the drawing the submerged apparatus is arranged so that minimum power is consumed prior to receipt of a first arming signal. Upon receipt of that signal the submerged receiving apparatus is armed to receive the interrogation signal. Having received the interrogation signal the submerged receiver then arms another of its sections to make it respond to command signals. Thus in this embodiment the submerged receiving apparatus undergoes two arming procedures. The first is an enabling step initiated by the receipt of a sonic signal comprising only one frequency component and that component is the one that originates in the interrogation coder oscillator 62 and passes through gate F1 for ultimate transmission by sonic transducer 60. A short time after gate F1 is opened and transmission of the signal has begun, gate F2 is opened and a second signal of different frequency is transmitted from sonic transducer 60. The combination of these two frequency components comprises the interrogation signal. Gates F1 and F2 are opened by signals derived from the repetition rate generator 56. The output of generator 56 is applied to a one-shot pulse generator 82 whose output is applied to an OR-gate 83. OR-gate 83 has another input which will be described later. At this point the function of the OR-gate 83 is to pass the pulse generated in one-shot pulse generator 82 to open the gate F1 for a predetermined period during the interrogation procedure. The output of repetition rate generator 56 is also applied to a delay circuit which in this embodiment has the form of a one-shot multivibrator 84 whose output is applied to a one-shot pulse generator 85. The output of the pulse generator is applied to

an OR-gate 86 which supplies a pulse to turn on gate F2. Thus the pulse output from repetition rate generator 56 is applied to both gate F1 and F2 to open them. However, the signal applied to gate F2 passes through the delay one-shot multivibrator 84 whereby the gate F2 is opened at a later time than is the gate F1.

In this embodiment the submerged, controlled station receiver is sensitive to the duration of the interrogation signals. A sonic signal containing a single frequency component through gate F1 is interpreted as an instruction to arm that portion of the receiver which responds to the interrogation code. That latter portion of the receiver, the portion that responds to the interrogation code, responds when the received signal includes the two frequency components passed through gate F1 and F2 but it responds only after having been armed by receiving the single frequency signal initially.

When the command switch 77 is actuated to send a pulse to closed gate 76 or the opened gate 78, a pulse is also sent to the one-shot multivibrator 90 the output of which is a very long pulse which is applied to OR-gates 83 and 86. Application of this long pulse to the two OR-gates results in the application of turn on signals to gate F1 and gate F2 simultaneously. They are turned off for a period considerably longer than the period over which they are turned on by pulses from the one-shot multivibrator 82 and 85. The result is the transmission by sonic transducer 60 of a dual frequency continuous wave signal over a substantial period of time. At the submerged, controlled receiver the duration of that signal is measured and the fact that it continues for a period longer then a prescribed time is made the occasion for arming that portion of the submerged receiver which responds to command signals transmitted by the sonic transducer 61 of the controlling station transmitter. The result is a system in which sonic signals employing components of only a few frequencies and a simple time duration code, and therefore which comprises a minimum number of components, can provide a coded range finding, identifying, interrogation, arming and commanding unit providing a very high degree of security against actuation by naturally occurring sonic signals and by manmade signals inclu;ing signals produced by intended intruders using the most versatile pulse sweep generators.

One of the advantages of systems embodying the invention is that the apparatus at the remote location may be relatively simple. This is illustrated in FIG. 2 which shows a block diagram of a remote, submerged, controlled receiving and transmitting unit. While other remote apparatus may be employed this particular form of apparatus has special advantages. The remote receiver includes two sections each with its own hydrophone. One receiving section actuates the sonic transmitter to make it respond to interrogation and to enable a command section of the receiver. The hydrophone of this section is represented by the block diagram 91 which receives sonic signals and converts them to electrical output signals which are applied to a wide band amplifier 92. The amplifier is provided with automatic gain control represented by the block 93. The output of the wide band amplifier is applied to four filter circuits two of which are tuned to pass signals having frequency components correspon;ing to those expected to be transmitted by sonic transducer 60 of the unit of FIG. 3. Two other of the filters are tuned to frequencies likely to be generated naturally along with the expected frequencies or likely to be generated in an unauthorized attempt to find the code. Thus they may be tuned to frequencies likely to be found in a broad band signal or in a multiple frequency sweep. The filters for expected frequencies are labeled "GO filters" and the other two filters are designated "NO GO filters." The GO filters are designated by reference numerals 94 and 95. The NO GO filters are labeled 96 and 97, respectively. GO filter 94 and NO GO filter 96 have their output circuits connected to amplifiers 98 and 99, respectively. The outputs of these two amplifiers are applied to a differential amplifier 100. GO filter 95 and NO GO filter 97 have their outputs connected to amplifiers 101 and 102, respectively. The outputs of these two amplifiers are applied across differential amplifier 103. One output of the differential amplifier 100 is integrated, as indicated at block 104, and the integrated output signal is applied to a power latch 105. In its quiescent condition this apparatus is without power except at hydrophone 91, wide band amplifier and AGC system 92 and 93, filters 94, and 96, amplifiers 98 and 99, differential amplifier 100, integrator 104 and power latch 105. Upon closure of the power latch 105 the remainder of the interrogation response and arming receiver section is energized. Output from both differential amplifiers is applied to an AND-gate 106. If both "GO" frequencies are received, and provided that neither "NO GO" frequency is received, a signal will appear at the output of AND-gate 106. This signal is applied to two integrators, one a continuous signal integrator 107 and the other a pulse integrator 108. Output of the latter is applied through a lock out circuit 109 to a pulse gate 110 provided that the pulse integrator output continues beyond the short time over which the lock out 109 is effective whereby to insure the noise spikes do not actuate the pulse gate 110. However, when a signal is permitted to proceed to the gate 110 it is applied to AND-gate 111. The other input to the AND-gate is supplied by a sonic oscillator 112 capable of providing a signal on any of three frequencies depending upon the position of limit switches 113 which are operatively associated with the apparatus to be controlled such that the switch circuitry is indicative of the operating condition of the apparatus to be controlled, here the valve 22 in pipeline 20. The frequency of the output of sonic oscillator 112 is then determined by the operating condition of the apparatus to be controlled as indicated by its limit switches 113. This signal is applied through the AND-gate 111 to the sonic transmitter 114 which sends a signal at a frequency which will result in the appearance of an output signal at the output terminals of one of the detectors 43, 44, or 45 of the apparatus of FIG. 3. The time of that transmission is determined by the characteristics of pulse gate 110.

Output from the continuous wave signal integrator 107 is applied to a threshold detector 115 and, having sufficient amplitude, is applied to a timed power latch 116. The power latch has two functions. It applies power to the command receiver section of the remote station for a selected period of time, a 2-second interval in this embodiment, during which the command section of the remote receiver is capable of receiving command signals from the unit FIG. 3. The limit switch 113 supplies a command to a detent solenoid 117 which forms a part of the fluid apparatus of FIG. 4 and which is represented in FIG. 2 by the block labeled MAIN VALVE ACTUATOR and designated by the reference numeral 118. The actuator includes a pilot valve structure and a valve operator 164.

The command section of the receiver of the remote station includes a hydrophone 125 whose output is applied to a wide band amplifier 126 which is provided with an automatic gain control circuit 127 and whose output is also applied to four filters designated 128, 129, 130 and 131 respectively. The output of filter 128 is applied to an amplifier 132. The output of filters 129, 130 and 131 are applied to amplifiers 133, 134, and 135, respectively. The output of amplifier 132 is applied to differential amplifiers 136 and 137. The output of differential amplifier 133 is applied to the same differential amplifiers. The output of each of amplifiers 134 and 135 is applied to each of the differential amplifiers 138 and 139. The output of differential amplifier 136 and the output of differential amplifier 138 are applied as the two inputs to an AND-gate 140. The output of differential amplifier 137 and the output of differential amplifier 139 are applied as the two inputs to an AND-gate 141. If an output appears at one of the filters 128 and 129 and not the other then an output will appear in the output circuit of each of differential amplifiers 136 and 137 and the signal will appear at one input of each of the AND-gate 140 and 141. One of these signals will be negative and one will be positive. Similarly if a signal appears at the output of one and not the other of filters 130 and 131 both of the differential amplifiers 138 and 139 will provide an output

signal to the other input of each of the AND gates. The polarity of those signals depends upon which of the filters **130** and **131** provided an output. Whichever of the two filters **128** and **129** provides an output, and whichever of the two filters **130** and **131** provides an output, the input signals to one AND gate will correspond in polarity and they will differ in polarity at the other. Accordingly, one AND gate will provide an output and one will not. When the AND-gate **140** provides an output that output is applied to an integrator **150** whose output is applied to a threshold detector **151** and the detected signal is applied to a "CLOSE SOLENOID" **152** which is actuated to operate one of the valves of the pilot valve of actuator **118**. When the AND-gate **141** provides an output it is applied to integrator **153** whose output is detected in threshold detector **154** and applied to "OPEN SOLENOID" **155** which also actuates a gas valve in the pilot valve of actuator **118**. It is not essential that the actuator **118** be gas powered. In this application a gas actuator is preferred. A suitable and advantageously employed hydraulic actuator is illustrated schematically in FIG. **4**. The structure of FIG. **4** includes two three-way gas valves which are actuated by the solenoids **152** and **155** of FIG. **2**. It also includes a three land, four-way, spool-type control valve coupled to a parallel spool to provide a mechanical balance against shock which incorporates a solenoid operated detent mechanism. Referring to FIG. **4**, the four-way spool valve is generally designated **160**. This is a three-position valve. It controls the flow of fluid from a pressure inlet port **161** to either of two outlet ports **162** and **163** depending upon whether the spool is moved downwardly or upwardly. When the spool is moved upwardly operating fluid is permitted to flow from inlet **161** to outlet **163** to one side of the vane motor-type valve operator **164** whose output shaft is connected to the ball valve **22** in FIG. **1**. The other side of the valve operator is exhausted through outlet **162** and drain opening **165**. When, instead, the spool is moved downwardly, then pressurized gas is permitted to flow from port **161** through outlet **162** into the rotary vane motor chamber to rotate the vane in the opposite direction, exhausting gas from behind the vane through outlet **163** to the drain passage **166**. Means are provided in this gas system for insuring that any shock forces applied to the control valve spool are balanced. Two piston structures are employed. One piston structure is generally designated by the reference numeral **170**. It includes a piston section **171** which corresponds to the other piston section **172** or "the spool." At its upper end, in FIG. **4**, the piston **170** is connected to the end of a shaft **173** whose center portion **174** has reduced diameter. Two spring glands **175** are mounted on that restricted portion **174** of the shaft. The spring glands are trapped so that they may not move further apart then they are shown to be in FIG. **4**. A spring **176** urges them apart. The section of shaft **173** behind each spring gland is larger than the opening through the gland in which the reduced portion **174** of the shaft is disposed. When piston **171** is moved upwardly the lower one of the two spring glands **175** is forced upwardly against the bars of spring **176** but the upper spring gland **175** does not move. Conversely, when the piston **171** is moved downwardly the lower of the two spring glands **175** does not move but the upper one is forced downwardly against the bars of spring **176** by the enlarged outer end of the shaft **173**. Thus the two spring glands **175** and the spring **176** serve as a centering mechanism to maintain piston **171** in an intermediate position.

A rocker arm **180** is pivoted on an axis midway between pistons **171** and **172**. Its ends fit in notches in the sides of pistons **171** and **172** whereby when one piston is advanced the other is retracted. A detent mechanism **181** operated by solenoid **117** serves to latch the rocker arm to hold the two pistons **171** in one of three positions. The apparatus is shown in the center one of those three positions in which the spool **160** of the control valve occupies a midposition. The detent **181** will also hold the spool in its up position or to its down position if the solenoid **117** is deenergized while the latch is in one of those positions.

The numeral **182** designates an inlet port for pressurized operating gas to the three-way ball-type pilot valve which controls the application of fluid pressure to the cylinder space **183** below spool piston **172**. The ball **184** of that valve is shown extended to close the pressure port **182** and open the cylinder chamber **183** to drain port **185**. When the solenoid **152** is energized the ball **184** is retracted to close the drain port **185** and to admit pressurized gas from inlet port **182** into the chamber space **183**. The pressurized fluid will force the piston **172** upwardly permitting the flow of pressurized gas from inlet port **161** to the outlet **163** whereby the vane **164** will be turned in the direction to close the valve **24**.

The other three-way valve is actuated by solenoid **155**. The solenoid controls movement of a ball **186** shown in FIG. **4** in extended position to close inlet pressure port **187** whereby the chamber space **188** below piston **171** is connected to the drain port **189**. When the solenoid **155** is energized the ball **186** is retracted to close the drain port and to admit pressurized gas from inlet port **187** into the chamber space **188**. As a consequence the piston **171** is forced upwardly causing the rocker arm **180** to rotate about its pivot forcing the piston **172** down whereby the spool of the control valve moves down to permit the flow of gas from inlet port **161** to outlet port **162**, into the vane motor which is made to rotate in a direction to open the valve **24**.

The gas or hydraulic fluid employed to actuate the pilot valve and the valve operator may be stored under pressure in a vessel submerged with the controlled station. It may be possible to utilize the pressure of fluid in the submerged pipe line and even to utilize some of the fluid carried in the pipeline to serve as the fluid medium through which control is exercised. Other possibilities are also presented. Energy in the fluid carried in the line may be used to generate enough power to make the battery pack unnecessary.

Where the valves are near an off-shore surface platform, power might be supplied by cables from the platform. Less often it could even be supplied from shore. But utility of the invention does not depend upon such easily available power sources. It is a feature of the invention that power is conserved when the system is quiescent without compromising its security. In this embodiment the controlled station is capable of receiving and responding to signals having eight different frequencies but need listen for only one of them in its quiescent state. This arrangement results in a system which is essentially "fail-safe" in the sense that failure of almost any component in the system results not in depletion of the power source but results only in failure of one function to be performed. Thus the invention can provide a highly reliable system. For example, even if a failure disables the system so it will not actuate the main valve on command, the system may still operate to aid in valve location so that a diver may then actuate the valve by hand as by manually rotating a handle on the shaft **200** whereby the rocker arm **180** is rotated.

The fact that a single frequency signal arms or enables the submerged, controlled station does not degrade the security of the system because obedience to commands is conditioned upon receipt of certain signals for not less than a given time and upon receipt of other signals, and nonreceipt of still other signals, in that time. This is the preferred type of code and is the one used in the embodiment described. In that embodiment, two signals of given frequency must coexist for a rather long time. Two others must be received during that time over a period during which two others may not be received. Such a code is very difficult to discover but requires only a minimum of equipment to generate and detect.

We claim:

1. In the method of receiving a control signal at a remote station from a control station and furnishing a signal at the remote station only if the control signal includes components at a plurality of frequencies, the improvement which comprises the steps of:

determining if said control signal includes each component of a first plurality of frequency components simultane-

ously for a predetermined period and only if it does, subsequently determining if said signal further includes, simultaneously with one another and with said first plurality of components, a second plurality of frequency components; and

furnishing said signal if said control signal is determined to include said first and second plurality of frequency components and if the components of said first plurality are simultaneously received for said period and if the components of said second plurality of components are received thereafter simultaneously with one another and with said first plurality of components.

2. The invention defined in claim 1 which comprises the further step of determining whether any of a third plurality of frequency components have been received at said remote station with said control signal; and

failing to furnish said signal if any component of said third plurality of signal components is received during said period.

3. The invention defined in claim 2, which comprises the preliminary steps of transmitting less than all the first plurality of components of said control signal for a time prior to said predetermined period and undertaking to determine if said first plurality of components is contained in the control signal for said predetermined period only if said signal has been determined to include less than all of them at said previous time.

4. The invention defined in claim 3 including the further step of transmitting a status signal from the remote station at a given interval following receipt of said control signal with less than all of said first plurality of components, and counting time from the time of transmission of said control signal with less than all of said first plurality of components until receipt at the controlling station of the status signal.

5. In a high security signalling system in which a remote receiving station is to respond only to signals from a controlling transmitting station; the improvement which comprises:

means at the transmitting station for sending the signal for a period of time which for a first portion of that period includes a component at a first given frequency and does not include a component at a second given frequency, and which in a subsequent portion of the same period, includes components at both of said first and second given frequencies; and

means at the remote station for receiving the signal and for responding thereto by placing itself in condition to respond to simultaneous receipt of the components at first and second frequency if, prior to their receipt, it receives a component at first frequency and not the component at second frequency.

6. The invention defined in claim 5 in which said subsequent portion of the period constitutes a time period having not less than a given duration and in which said means at the transmitting station for sending a signal includes means for sen;ing a signal including said component at first frequency and said component at second frequency simultaneously throughout said given period; and

in which said means at the remote station for receiving the signal includes an arming apparatus whose state can be changed, and means for changing the state of said arming apparatus if, but only if, the signal received at said remote station includes a component at said first given frequency and a component at said second given frequency simultaneously for not less than said given time and only if the signal received at said remote station fails to include components at either of two other given frequencies at any time during said given time.

7. The invention defined in claim 6 which further comprises means at said transmitting station for sending a second signal incorporating frequency components at other than said first and second given frequencies simultaneously with the sending of said first mentioned signal;

said remote station further comprising means for performing a controlled function in response to receipt of said second signal while said arming apparatus is armed.

8. The invention defined in claim 7 in which said remote station comprises means for providing a signal indicative of the state of the controlled function and a transmitter responsive thereto and to receipt by said remote station of a signal including component at said first given frequency in the absence of a component at said second given frequency for transmitting a signal indicative of the state of said condition, and

in which said transmitting station includes receiving means for receiving a signal transmitted by said remote station.

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