Jan. 21, 1947. R. B. SHANCK 2,414,488

HEAT RESPONSIVE COMMUNICATION SIGNAL REPEATER

Filed July 22, 1942

FIG. 1

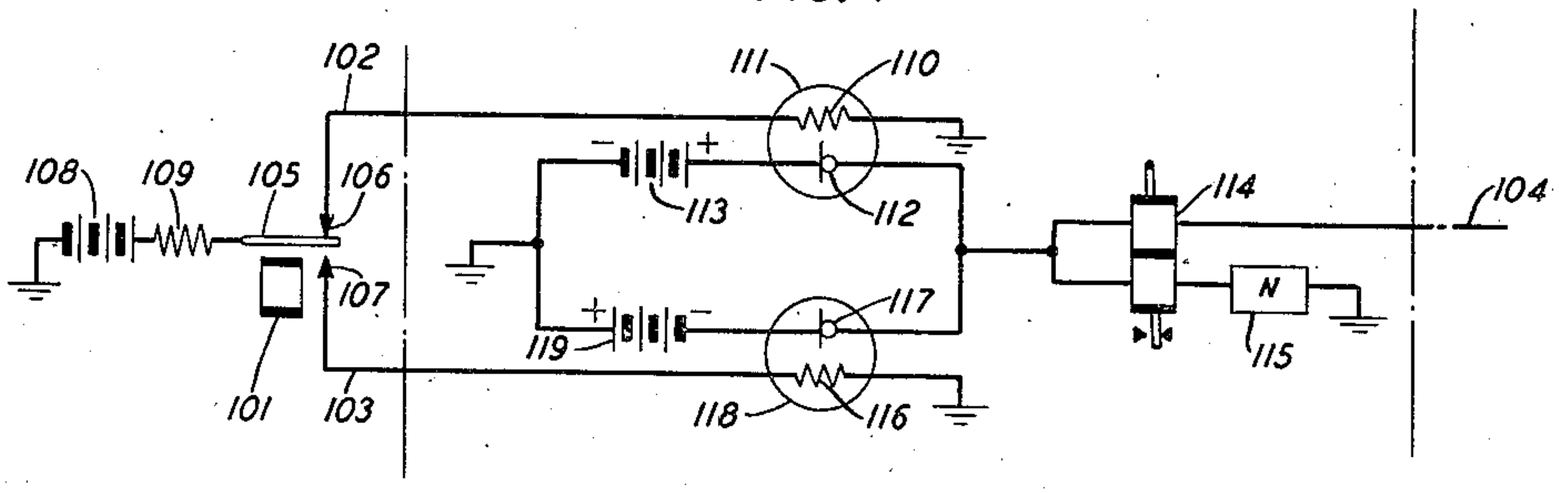


FIG. 2

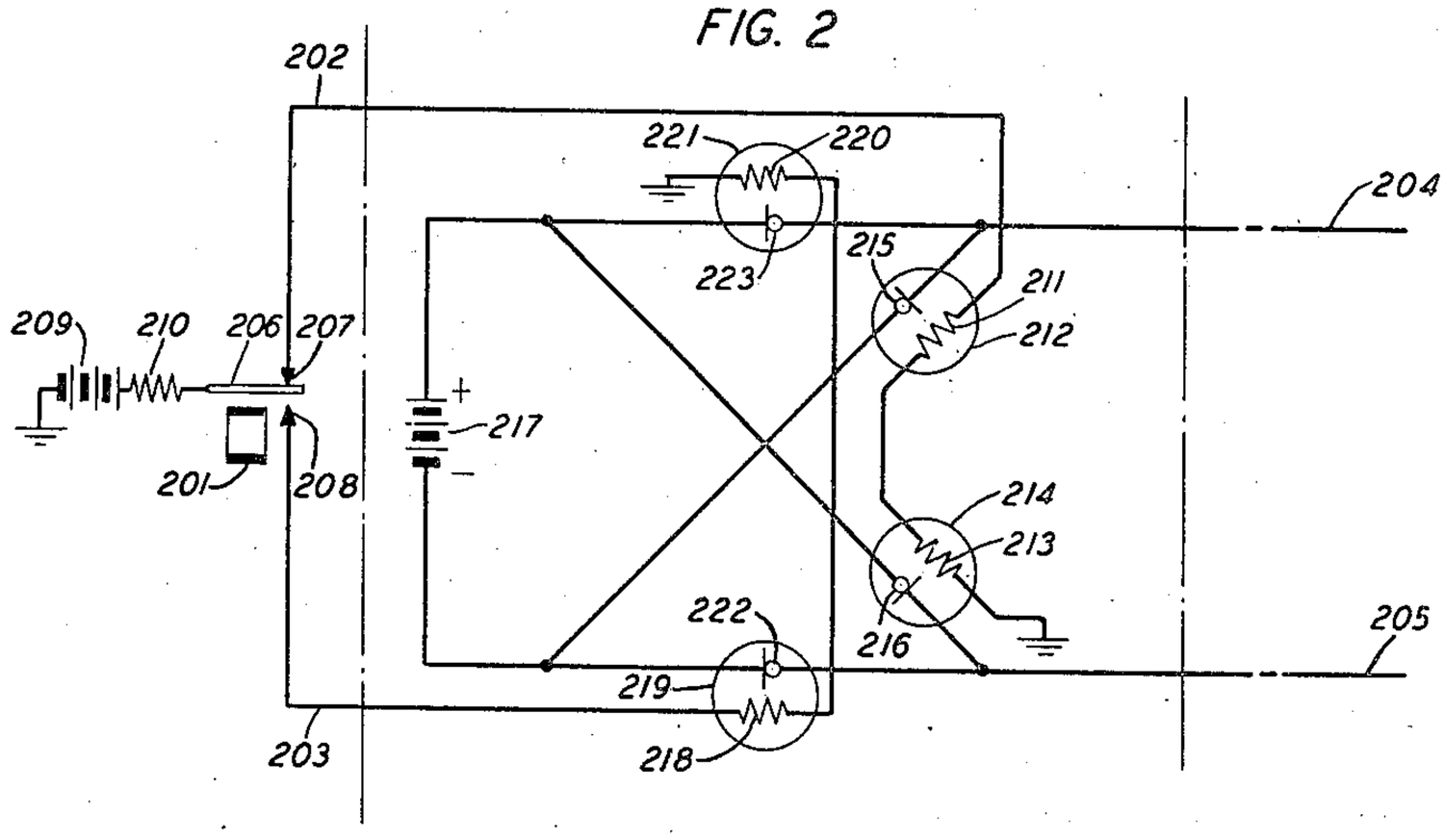
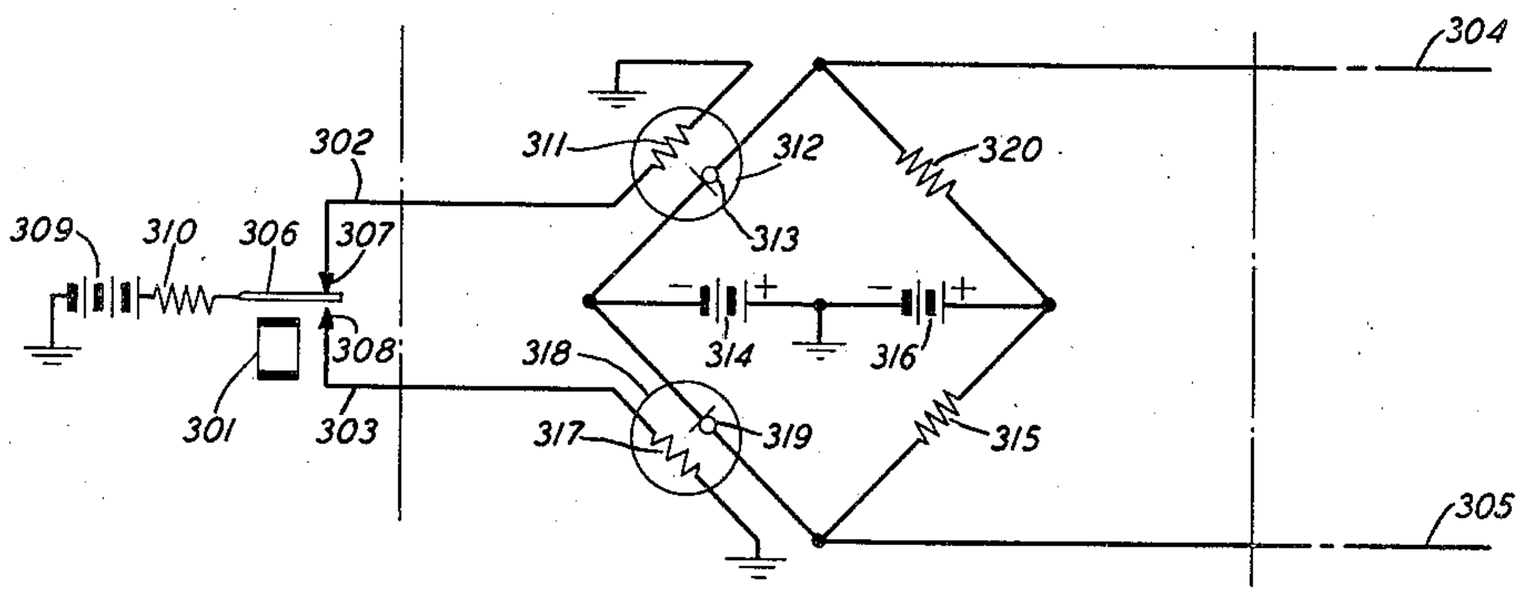


FIG. 3



INVENTOR
R. B. SHANCK

BY J. W. Schmied

ATTORNEY

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HEAT RESPONSIVE COMMUNICATION SIGNAL REPEATER

Roy B. Shanck, Douglas Manor, N. Y., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

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13 Claims. (Cl. 178—70)

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This invention is a communication signal repeater responsive to changes in heat.

An object of the invention is the improvement of repeaters in communication circuits.

A feature of the invention is the employment of a resistance the magnitude of which is varied in response to changes in heat as a repeater for communication signals.

One specific form of resistance which varies in magnitude in response to changes in heat suitable for use in practicing this invention comprises an element commonly classed as a semiconductor possessing the characteristic of substantial change in resistance with change in temperature. Such materials may be employed to form circuit elements by fusing or otherwise binding platinum or other conductor leads into electrical contact with a suitable quantity of semiconductor compound. These elements are ordinarily of comparatively high resistance but as the temperature is raised, either because of an external heater or because of the heating effect of such current as is flowing through the element, the resistance falls very greatly. The device therefore takes on the nature of a switch or, as employed in this invention, as a valve, in which the control is exercised through change in temperature. Devices of this kind have been called "thermistors."

Incorporated herein by reference are the following patents disclosing thermally sensitive resistors with which the invention herein may be practiced: G. L. Pearson 2,184,847, December 26, 1939; G. L. Pearson et al, 2,253,577, August 26, 1941; G. L. Pearson 2,280,257, April 21, 1942; and G. L. Pearson 2,276,864, March 17, 1942.

In the invention herein communication signal current pulses are translated into variations in heat. The heat changes are impressed on a resistance, the magnitude of which varies in response to heat changes. The heat responsive resistance controlled by communication signals is arranged to act as a valve to regulate the flow of current in a second circuit in response to communication signals in a first circuit. The two circuits may be coupled solely by means of a heat transfer element in which case the circuit in which the communication signals originate and the circuit into which they are repeated may be otherwise independent. Or the communication signal current may flow directly through the heat responsive reactance so that the two circuits are electrically as well as heat coupled.

Heat responsive resistors or "thermistors" as they are known in the art are presently available which respond satisfactorily to current changes of a frequency even beyond 10,000 cycles per second. Such "thermistors" are described in Patent 2,276,864 mentioned above. Various applications of these thermistors are described in my copending application Serial No. 451,905, filed July 22, 1942. Their use is feasible, therefore, as communication signal repeaters, not only in telegraph systems, both of the direct and alternating current types, including carrier current telegraph systems, but also in telephone systems including both those operated at speech current and carrier current frequencies up to the upper frequency limit of the response of the thermistor.

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The thermistors intended to be used in this invention are all types in which the resistance change in response to heat change is satisfactory for the signaling speed employed in whatever communication system and includes all types of thermistors from those of relatively slow response to the modern ultra fast response of 10,000 cycles per second and upward.

It is to be understood that the heat responsive "thermistor" type repeaters, whether used in telegraph or telephone systems or in other systems may be connected in tandem through as many repeating stations without limit as may be required for any case either with or without other intervening repeaters.

Further, this invention specifically comprehends the employment of the heat responsive "thermistor" type communication signal repeaters in radio transmitters and receivers of all types, both in broadcasting and receiving speech and music and in television broadcasting and receiving. In general it may be substituted widely for vacuum tubes for many purposes to effect a saving in first cost and operating expense.

The invention is embodied in telegraph circuits but it is to be understood that the invention is not limited to telegraph circuits and may be applied in the repeating of speech signals in telephone communication, in the repeating of signals in picture transmission, in the repeating of signals in telemetering circuits, remote control circuits and in many other circuits.

The invention may be understood from the following description when read with reference to the associated drawing, in which:

Fig. 1 discloses the heat-responsive repeater applied in a direct current telegraph circuit arranged for the transmission of polar signals;

Fig. 2 discloses a heat-responsive repeater in a direct current telegraph circuit arranged for

the full commutation of a direct current telegraph battery in a one-way, two-wire circuit; and

Fig. 3 discloses the embodiment of a heat-responsive repeater of a form different from Fig. 2 but arranged also to provide full commutation.

Refer now to Fig. 1. Relay 101 is assumed to be located at a first telegraph station. It is connected by means of two conductors 102 and 103 to the heat-responsive repeater located at a second telegraph station. The heat-responsive repeater is connected by means of conductor 104 to a third telegraph station, not shown. As the winding of relay 101 is energized and deenergized, its armature 105 is actuated between its contacts 106 and 107. When armature 105 is in engagement with contact 106, a circuit may be traced from ground, through battery 108, resistance 109, armature 105, contact 106, conductor 102 and the resistance heating element 110 of thermistor 111 to ground. When current flows in this path the temperature of resistance unit 110 is raised. This, in turn, raises the temperature of the heat-responsive resistance element 112. The resistance of heat-responsive resistance element 112 is reduced and a voltage pulse from grounded positive battery 113 is impressed through the upper winding of polar relay 114 and conductor 104 to the distant station. Simultaneously current flows through the bottom winding of relay 114 and through the artificial line 115 to ground. The net effect of the current flowing in the two windings of relay 114 maintains the armature of relay 114 in engagement with its marking contact. When the armature of relay 105 is operated so as to engage with contact 107, a circuit is established from ground through battery 108, resistance 109, armature 105, contact 107, conductor 103, and resistance heating element 116 of thermistor 118 to ground. Resistance heating element 116 is raised in temperature. The heat-responsive repeating element 117 of thermistor 118 is also raised in temperature lowering its resistance. A negative pulse from grounded negative battery 119 is impressed through repeater 117, the top and bottom windings of relay 114 and conductor 104 to the distant station. The net effect of the current in the two windings of relay 114 again maintains the armature of relay 114 in engagement with its marking contact in a well-known manner.

Refer now to Fig. 2. Relay 201 is located at a first telegraph station. It is connected to the heat-responsive repeater by conductors 202 and 203. The heat-responsive repeater is located at a second telegraph station and it is connected to a third telegraph station by means of conductors 204 and 205. As the winding of relay 201 is energized and deenergized, armature 206 is operated between its contacts 207 and 208. When armature 206 is in engagement with its contact 207 a circuit is established from battery 209, through resistance 210, armature 206, contact 207, conductor 202, resistance heating element 211 of thermistor 212, and resistance heating element 213 of thermistor 214 to ground. The temperatures of resistance heating elements 211 and 213 are raised, in turn, raising the temperatures of the heat-responsive repeating elements 215 and 216 of thermistors 212 and 213, respectively. The resistances of repeating elements 215 and 216 are lowered. A circuit may then be traced from the positive terminal of battery 217, through repeating element 216, over conductor 205 to the distant station and returning over conductor 204, through repeating element 215 to the negative terminal of battery 217. When armature 206 of relay 201 engages contact 208, a circuit is established from ground, through battery 209, resistance 210, armature 206, contact 208, conductor 203, resistance heating element 218 of the heat-responsive repeater 219, and heating element 220 of heat-responsive repeater 221 to ground. The temperatures of resistances 218 and 220 are increased, in turn, increasing the temperatures of the repeating elements 222 and 223. The resistances of the elements are decreased. A circuit may then be traced from the positive terminal of battery 217, through repeating element 223 and over conductor 204 returning over conductor 205, through repeating element 222 to the negative terminal of battery 217. As a result of this the connections of the terminals of battery 217 to conductors 204 and 205 are alternately reversed.

In the embodiment shown in Fig. 3, relay 301 is located at a first telegraph station. It is connected to the heat-responsive repeater at a second telegraph station by means of conductors 302 and 303. The heat-responsive repeater is connected to a third telegraph station by means of conductors 304 and 305. The heat-responsive repeater elements are connected in a bridge, the resistances of the arms of which are equal when the heat responsive elements are cold. When relay 301 is energized and deenergized, armature 306 is actuated between its contacts 307 and 308. When armature 306 is in engagement with contact 307 a circuit is established which may be traced from battery 309, through resistance 310, armature 306, contact 307, conductor 302, and resistance heating element 311 of heat-responsive repeater 312 to ground. The temperature of the resistance heating element 311 is increased, in turn, increasing the temperature of the heat-responsive repeating element 313 of thermistor 312. The resistance of the heat-responsive element 313 is decreased. Current will thereupon flow from ground, through negative battery 314, repeating element 313, over conductor 304, returning over conductor 305, through resistance 315, and positive battery 316 to ground. When armature 306 of relay 301 engages with contact 308, a circuit is established from battery 309, through resistance 310, armature 306, contact 308, conductor 303, and resistance heating element 317 of thermistor 318 to ground. The temperature of resistance 317 is increased, in turn, increasing the temperature of repeating element 319. The resistance of repeating element 319 is decreased. Thereupon current flows from ground through negative battery 314, repeating element 319, over conductor 305, to the distant station, returning over conductor 304, through resistance 320 and positive battery 316 to ground.

The arrangement shown in Fig. 3 could be used for reversing the phase of an alternating current if batteries 314 and 315 were replaced by an alternating current generator.

It has been found that the heat-responsive repeater greatly reduces noise and it is to be understood that, if it is preferred, the apparatus described as being located at stations 1 and 2 may all be located at the same station to take greater advantage of this characteristic. As thus arranged the heat-responsive repeater would be controlled by a local circuit at the same station instead of being controlled from a remote station. The reduction in noise is so substantial that in

some cases the noise filters ordinarily required may be eliminated. In other cases they may be simplified.

It is to be understood that when the heat-responsive repeater is used for repeating speech signals, the telegraph equipment shown will be replaced by equipment responsive to speech. Relays 101, 201, 301 at office 1, for instance, would be replaced by a telephone transmitter. The heat-responsive repeater at office 2 would connect directly to a telephone line extending to office 3. Telephone receiving equipment would be installed at office 3 instead of telegraph receiving equipment. Corresponding changes, well understood, would be required when the heat-responsive repeater was used to repeat picture signals or to operate in remote control circuits, etc.

What is claimed is:

1. In a direct current telegraph circuit, a heat-responsive telegraph signal repeater for minimizing noise, means for varying the heat supplied to said repeater directly by the variations in received telegraph signal current and means for effectively reversing the terminals of a battery connected to a two conductor telegraph transmitting circuit in response to said received signal current.

2. In a direct current telegraph circuit, a heat-responsive telegraph signal repeater for minimizing noise, a plurality of resistances in said repeater, a plurality of heating elements individually associated with said resistances and means for simultaneously controlling the heating of said elements to vary the magnitude of said resistances to transmit telegraph signals in response to received telegraph signal current directly.

3. In a direct current telegraph circuit, a telegraph channel interconnecting two telegraph stations, a heat-responsive thermistor repeater in said channel, said repeater comprising a resistance through which attenuated, electrical telegraph signals are conducted to generate in said resistance corresponding variations in heat energy and means directly responsive to said heat energy variations for regenerating amplified signals corresponding to said telegraph signals, to reduce repeater noise by rounding the beginnings and the ends of the waves of said regenerated signals, through the heating and cooling time lag of said resistance.

4. In a direct current telegraph system, a polar telegraph thermistor repeater circuit for minimizing noise, by rounding the beginnings and ends of regenerated telegraph signals through thermal lag, said circuit having a first output branch extending from grounded negative battery through a first thermistor variable resistance element to the line winding of a telegraph receiving relay and a second output branch extending from grounded positive battery through a second thermistor variable resistance element to said winding, a thermistor heating resistance element in each of two input branches, thermally connected individually with each of said variable resistance elements, and means for varying the heat supplied to said heating resistance elements alternately in response to received telegraph signal currents directly.

5. In a direct current telegraph system, a polar telegraph thermistor repeater comprising two heat controlled variable resistance elements, means for alternately varying the amount of heat supplied to said elements in response directly to received telegraph signal current of the same polarity, and means in said repeater for generating polar signals having wave forms with rounded beginnings and ends, due to thermal lag, to minimize noise, in response to said variations in heat.

6. In a telegraph system, a bridge type direct current, thermistor telegraph repeater for minimizing repeater noise comprising four conjugate arms, each of two of said arms having a variable resistance thermistor element therein, each of said elements having associated therewith a heating resistance element responsive to changes in heat generated by telegraph signal currents directly for regenerating telegraph signals.

7. In a telegraph system, a direct current telegraph repeater for minimizing repeater noise, a first and a second thermistor in said repeater, a heating element and a variable resistance element in each of said thermistors, an incoming circuit, an outgoing circuit, two incoming branches in said repeater connected to said incoming circuit, two outgoing branches in said repeater connected to said outgoing circuit, a telegraph battery connected through said outgoing branches to said outgoing circuit, one of said heating elements in each of said incoming branches, one of said variable resistances in each of said outgoing branches, means in said incoming circuit for impressing telegraph signal current impulses on each of said incoming branches to heat said heating elements, and means in said repeater responsive to the consequent variations in the resistances of said variable resistance elements, for effectively reversing the polarity of said battery connected through said outgoing branches to said outgoing circuit, to regenerate said impulses, impressed by said incoming circuit, in said outgoing circuit.

8. In a telegraph system, a direct current telegraph communication signal repeater for reducing repeater noise, a thermistor in said repeater, a heating element in said thermistor, a variable resistance element in said thermistor responsive to heat changes in said element, a receiving relay in said repeater, a telegraph transmitting and receiving circuit connected directly to said resistance, said relay in said repeater having an operating winding in series in said circuit, means connected to said repeater for transmitting telegraph communication signal current impulses through said heating element, means responsive to heat changes in said element effected by said signals for repeating said signals through said variable resistance and said relay winding in a first direction at a first time, and means responsive to other telegraph signal current impulses incoming through said winding and directly through said variable resistance in a second direction for receiving said other signals at a second time.

9. In a telegraph system, a direct current telegraph repeater for minimizing noise, a thermistor in said repeater, a heating element in said thermistor, a variable resistance element controlled by said heating element in said thermistor, a one-way telegraph circuit connected directly to said heating element, a two-way telegraph circuit connected directly to said variable resistance, means for impressing telegraph signal current impulses on said heating element, means responsive to heat changes effected by said impulses for repeating said signals directly through said variable resistance and said two-way circuit in a first direction at a first time, and means for receiving current impulses corresponding to other telegraph signals directly through said two-way circuit and

said variable resistance in a second direction at a second time.

10. In a telegraph system, a direct current telegraph repeater for minimizing noise, a thermistor in said repeater, a heating element in said thermistor, a variable resistance responsive to heat changes effected by said element in said thermistor, a one-way telegraph circuit connected directly to said heating element, a two-way telegraph circuit connected directly to said variable resistance, means connected to said repeater for impressing telegraph signal current impulses through said heating element, means responsive thereto for repeating said impulses directly through said variable resistance and said two-way circuit in a first direction at a first time, and means connected to said repeater for receiving telegraph signals impressed through said two-way circuit and directly through said variable resistance in a second direction at a second time.

11. In a telegraph system, a direct current telegraph repeater for minimizing noise, a one-way and a two-way telegraph circuit connected to said repeater, a first and a second thermistor in said repeater, a heating element and a variable resistance, responsive to heat changes in said element, in each of said thermistors, means in said one-way circuit for impressing telegraph signal current impulses of the same polarity alternately on said heating elements, means responsive to heat changes effected by said impulses for transmitting polar telegraph signals directly through said variable resistances and said two-way circuit in a first direction at a first time, a telegraph signal receiving device in sad two-way circuit, and means for receiving telegraph signal impulses directly through said receiving device and either of said variable resistances in said two-way circuit in a second direction at a second time.

12. In a telegraph system, a direct current telegraph repeater for minimizing noise, a two-conductor circuit incoming to said repeater, a two-conductor circuit outgoing from said repeater, four thermistors in said repeater, a heating element and a variable resistance responsive to heat changes in said element in each of said thermistors, a telegraph battery in said outgoing circuit, means connected to each of said conductors in said incoming circuit for impressing telegraph signal current impulses on said heating elements of a first and a second pair of said thermistors alternately, and means responsive thereto for transmitting telegraph signal current impulses of opposite polarities from said battery through said variable resistances of a corresponding first and second pair of said thermistors to said two-conductor outgoing circuit.

13. In a telegraph system, a direct current telegraph repeater for minimizing noise, a bridge having a first, second, third and fourth arm in said repeater, a two-conductor output circuit connected to a first pair of diagonally opposite terminals between said arms of said bridge, a telegraph battery connected to a second pair of diagonally opposite terminals between said arms of said bridge, a first and a second thermistor in said repeater, each of said thermistors comprising a heating element and a variable resistance element, said variable resistance element responsive to variations in heat of said heating element, one of said variable resistance elements in said first arm and another in said second arm, means for impressing telegraph signal current impulses on said heating elements alternately, and means comprising said variable resistance elements, responsive to said impulses for effectively reversing the polarity of said battery to repeat said impulses in said output circuit.

ROY B. SHANCK.