Nov. 12, 1935. E. T. BURTON 2,020,875

ENERGIZATION AND CONTROL OF AMPLIFIERS

Original Filed Dec. 31, 1931 4 Sheets-Sheet 1

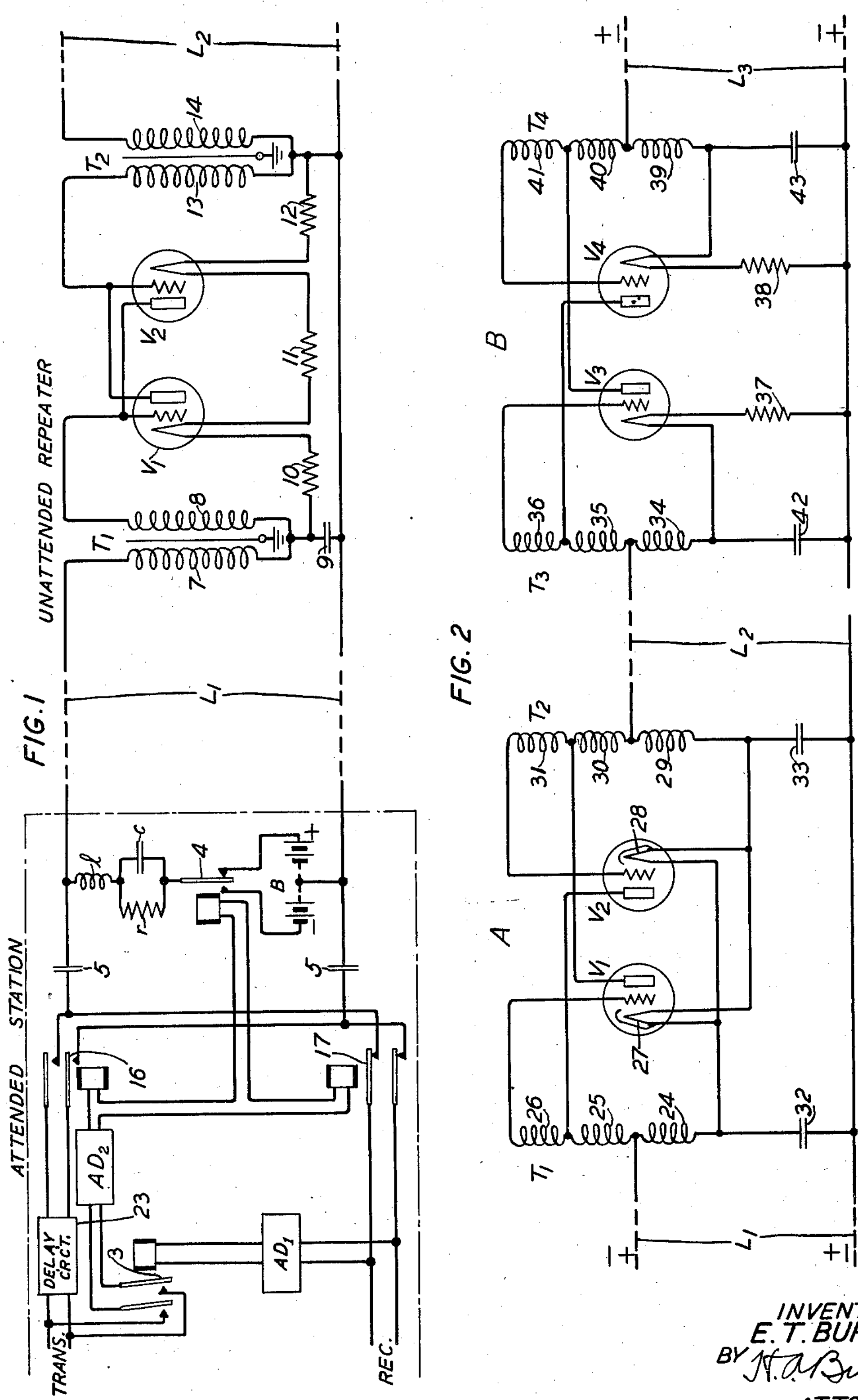

FIG. 1

FIG. 2

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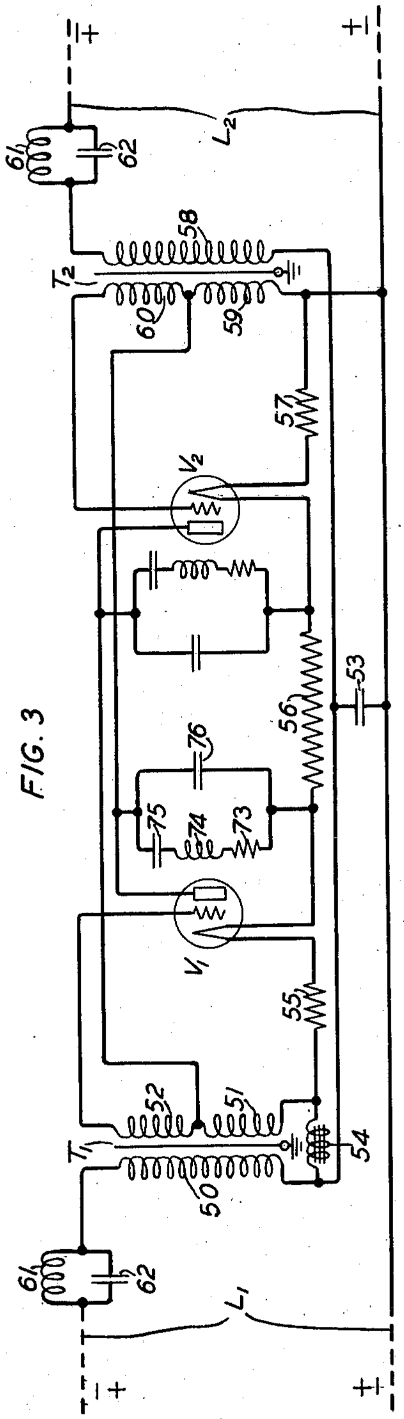

FIG. 3

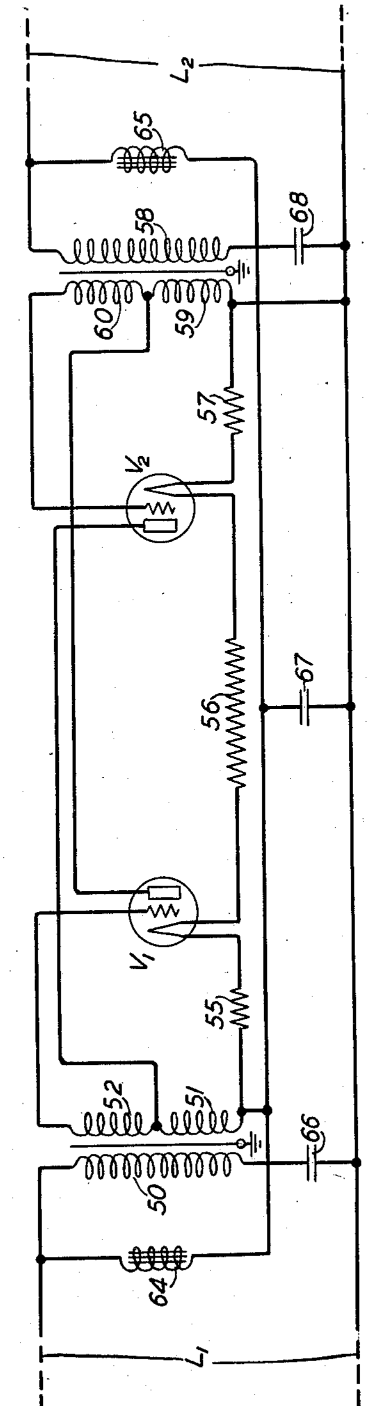

FIG. 4

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ENERGIZATION AND CONTROL OF AMPLIFIERS

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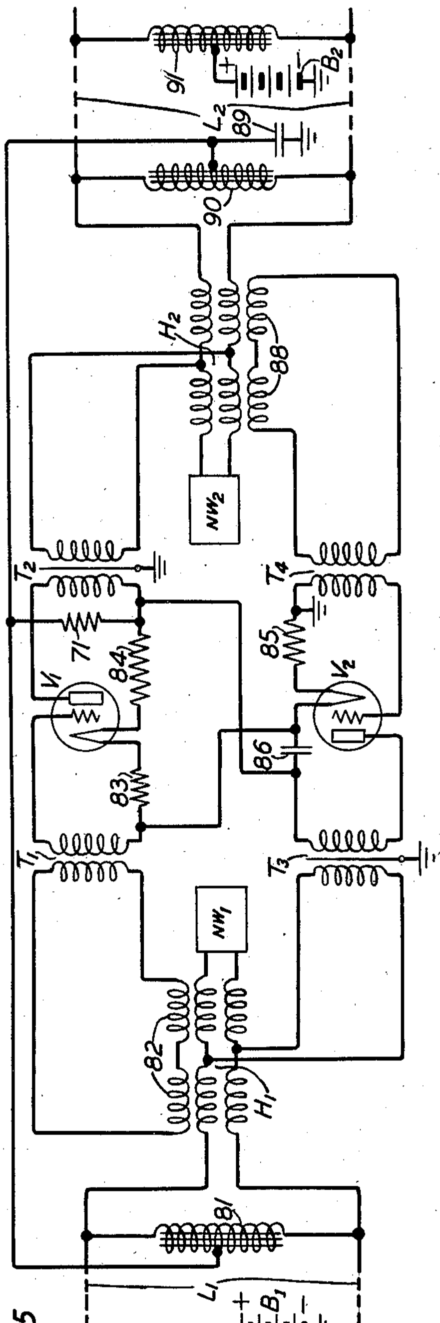

FIG. 5

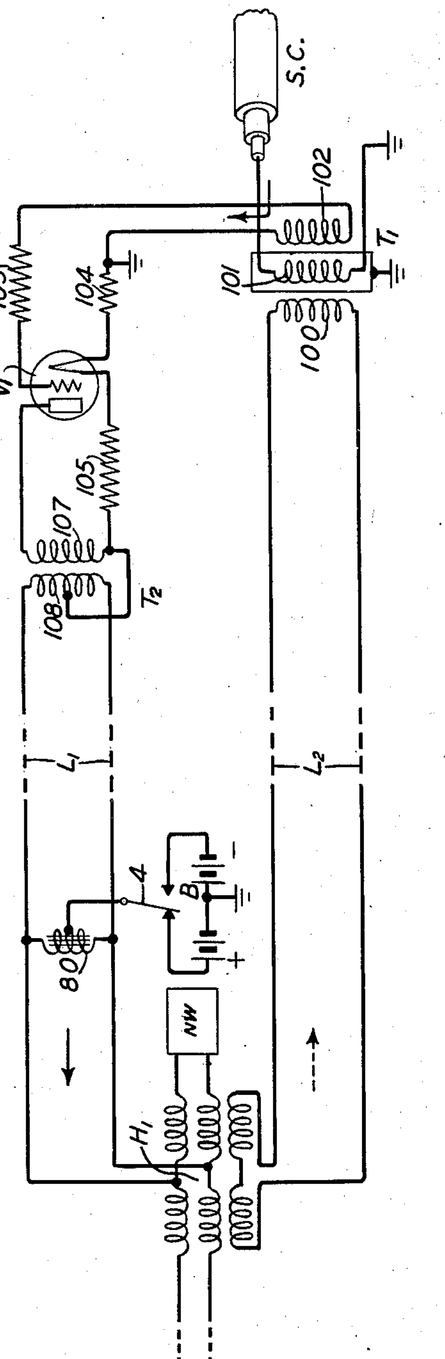

FIG. 6

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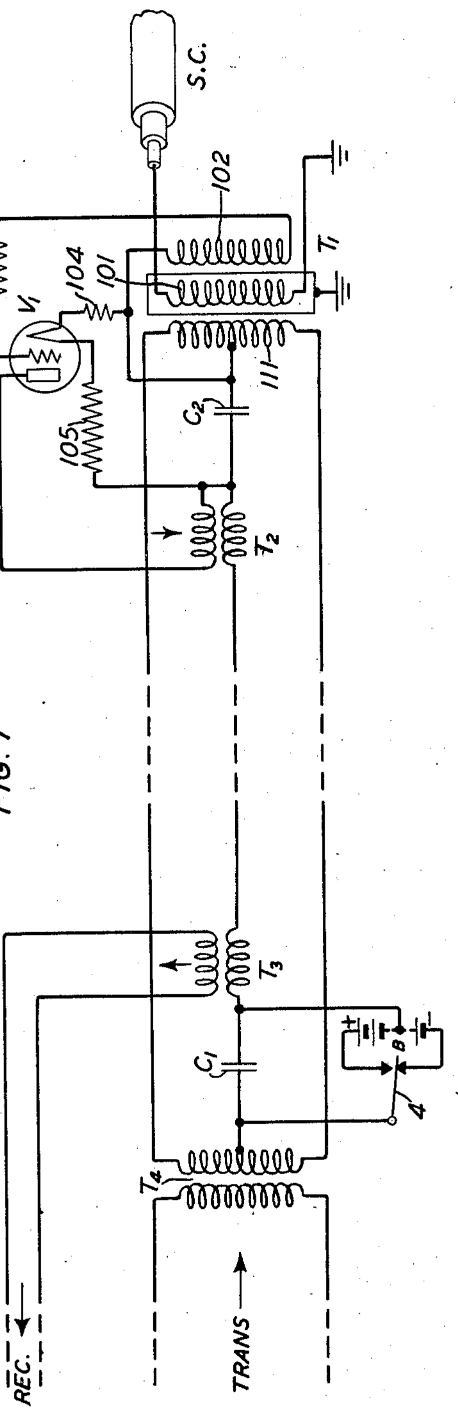

FIG. 7

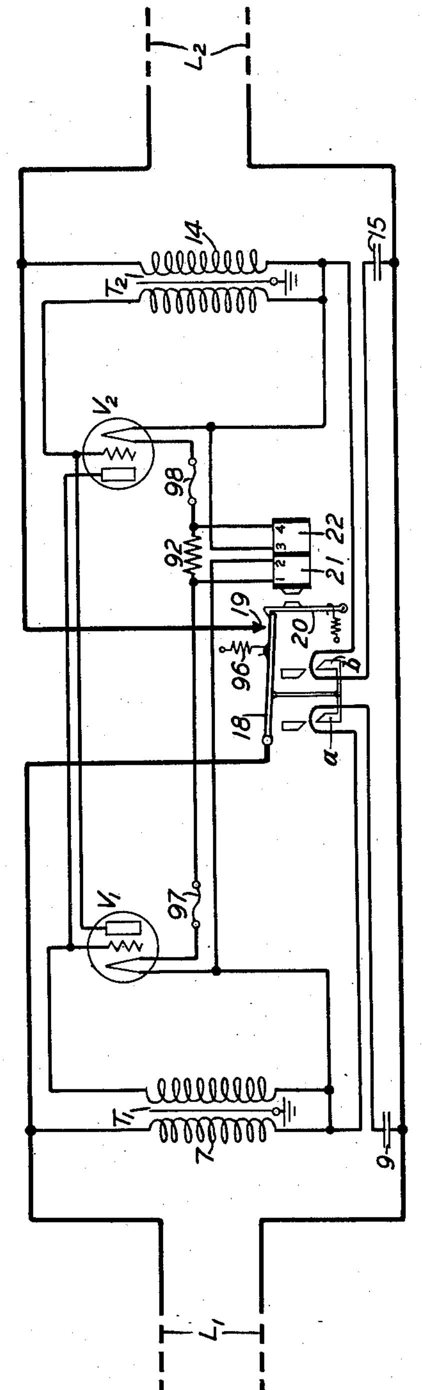

FIG. 8

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UNITED STATES PATENT OFFICE

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ENERGIZATION AND CONTROL OF AMPLIFIERS

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Application December 31, 1931, Serial No. 584,043

42 Claims. (Cl. 179—170)

This invention relates to electrical signaling systems and more particularly to conducting systems wherein an amplifier is energized or controlled from a remote point.

In the design of transmission systems the location of an amplifier at a particular point may practically be precluded by a number of factors, both economic and physical. In the design of a land system, for example, which is subject to the paramount consideration of reliability of service, repeaters are ordinarily limited to those locations where accommodations for an attendant to inspect and maintain the apparatus can be provided. The cost of individual power supply units for the amplifiers becomes another limiting factor when close spacing of repeaters is contemplated. Again, although it would be highly advantageous to insert an amplifier or series of amplifiers in a submarine cable system, the physical limitations involved are recognized as serious obstacles.

The present invention has for an object to simplify the construction and increase the reliability of an amplifier that is to be controlled or energized from a remote point. More particularly, the object is to provide an amplifier suitable for submarine locations.

A feature of the invention is that no moving parts are involved in the normal operation of the amplifier.

Another feature of the invention lies in the means provided for disconnecting the amplifier from the line if it becomes inoperative for any cause.

In a repeater comprising a pair of amplifiers adapted to amplify signals in opposite directions, a singing condition is liable to be established. Voice-operated relays and discharge devices have heretofore been used to disable one amplifier when signals are passed through the oppositely directed amplifier. The addition of mechanically operating devices and discharge devices, however, makes the amplifiers liable to disruption of service because of their failure to operate. Hybrid coils offer an alternative solution, but the degree of conjugacy obtainable is not in every case sufficient and their bulk and weight are objectionable.

Another object of the present invention is to provide a reliable system for controlling the direction of amplification of the repeater from a remote point, more particularly by disabling one amplifier in response to signals transmitted in the opposite direction.

In accordance with a third feature of the present invention, the direction of transmission through a repeater is determined by the polarity of a voltage applied to the signaling line at a terminal station or attended repeater station. By reversing the polarity of the voltage, the polarity of the operating voltages applied to the elements of the space discharge devices in the repeater, as, for example, the voltage applied to the anodes of these devices, can be altered to render one device or the other exclusively operative. All moving parts and voice-operated equipment may be located at a terminal station or at an attended repeater station where they can be periodically inspected and maintained in a proper operating condition.

Another limiting factor in the design of a system of the type contemplated, is the amount of power that can safely be transmitted over the signaling conductors. The conductors are usually designed primarily for the relatively small amounts of power that are encountered in signaling practice, and they may be seriously injured by the application of high voltages or large currents. The power requirements are especially likely to be excessive where power is to be supplied to several repeaters connected in tandem.

Applicant's invention is further featured in one of its embodiments by the supply of power to a repeater, or to a number of tandem repeaters, from both ends of the signaling line. The power level in the line is thereby reduced to approximately half that obtaining where all the power is supplied from one station.

Other objects and features will appear in the following description of several embodiments illustrative of the present invention. Reference will be made to the accompanying drawings, wherein

Fig. 1 shows schematically one form of half-duplex repeater in accordance with the present invention, together with terminal control and energizing circuits therefor;

Fig. 2 shows a form of half-duplex repeater that may be used where power is to be supplied to a plurality of repeaters connected in tandem, and a third type adapted to be supplied with power over the signaling line from both directions;

Figs. 3 and 4 show other forms of half-duplex repeaters, characterized by equalizers and power-current filters;

Fig. 5 shows a full-duplex repeater using hybrid coils and adapted to be supplied with power from both terminal stations;

Figs. 6 and 7 each show a submarine cable terminal system with an amplifier located at the cable head supplied with power over a signaling line from the terminal station proper; and

Fig. 8 shows a device for bridging the line around an unattended repeater whenever it becomes necessary as because of failure of the space discharge devices.

Referring now to Fig. 1, there is shown schematically an unattended vacuum tube repeater adapted for two-way transmission of signals between lines L_1 and L_2, which may be, for example, sections of a submarine cable. Operating voltages for the amplifier tubes are supplied over line L_1 from the attended station with which the unattended repeater is connected. Means, to be described hereinafter, are provided at the attended station for reversing the polarity of the source of operating voltage connected across line L_1, in accordance with the direction in which signals are to be transmitted. With a negative potential applied to the upper side of line L_1, amplifier tube V_1 of the repeater is rendered operative and amplifier tube V_2 inoperative, the repeater in this condition being adapted for W—E transmission. Reversing the potential applied to line L_1 renders amplifier tube V_2 operative and V_1 inoperative and thus adapts the repeater for E—W transmission.

The path of direct current applied to line L_1 may be traced from the upper side of the line through winding 7 of transformer T_1, resistor 10, the filament of V_1, resistor 11, the filament of V_2, and resistor 12 to the lower side of the line. The resistances of these several elements are such that the current allowed to flow through them is the current normally required by the filaments of the amplifier tubes. Resistor 10 is of relatively small magnitude. The voltage drop across it when the repeater is adapted for W—E transmission is transmitted through winding 8 of transformer T_1 to the grid of amplifier tube V_1 where it provides a suitable negative grid bias. Resistor 12, similarly, supplies a suitable bias for amplifier tube V_2 through winding 13 of transformer T_2 when signals are to be transmitted in the opposite direction. Resistor 11 is relatively large, and the greater part of the direct current voltage available at the repeater appears across it. The anode of amplifier tube V_1 is connected to the same terminal of winding 13 of transformer T_2 as the grid of amplifier tube V_2. Through this winding it is connected to the lower side of line L_1, which is positive with respect to the upper side of that line and with respect to the filament of tube V_1 when that tube is in the operative condition. At the same time, the anode of the other tube V_2 is negative with respect to its filament by virtue of its connection to the negative side of line L_1 through windings 7 and 8 of transformer T_1. Reversing the voltage applied to line L_1 reverses the potential distribution across the series-connected resistors 10, 11 and 12, and a positive anode voltage is provided for amplifier tube V_2, while a negative anode voltage applied to amplifier tube V_1 renders that tube inoperative.

Signals transmitted in the W—E direction are applied to winding 7 of transformer T_1. Condenser 9 in series with winding 7 serves as a direct-current blocking condenser and shunts the signals around the series-connected resistors 10, 11 and 12. The signals are then induced in winding 8 of transformer T_1 and applied to the input terminals of amplifier tube V_1. As a negative voltage is applied to the anode of the other amplifier tube V_2, its output impedance is high and the shunting effect on signals applied to tube V_1 is slight. The output circuit of tube V_1 may be traced through winding 13 of transformer T_2, condenser 9 and resistor 10. The amplified signals are applied to the line L_2 through winding 14 of transformer T_2, which is connected directly across that line.

In the E—W direction of transmission the signals are applied through transformer T_2 and grid biasing resistor 12 to the input terminals of amplifier tube V_2. The output circuit of this tube includes winding 8 of transformer T_1, condenser 9 and resistor 12. The amplified signals traversing this circuit are passed by transformer T_1 to line L_1 through condenser 9.

Any suitable apparatus may be used to reverse the polarity of the voltage applied to line L_1. That illustrated in Fig. 1 comprises a relay 4 and battery B, the respective terminals of the battery being alternatively connected to the upper side of line L_1 through the armature of relay 4, and the central point being connected to the lower side of the line. Relay 4 may be controlled by suitable voice-operated apparatus. In the circuit shown in Fig. 1 the winding of relay 4 is connected in series with the windings of relays 16 and 17 across the output terminals of an amplifier-detector AD_2 which is connected across the upper or transmitting side of the four-wire terminal circuit through the contacts of relay 3. Normally, i. e., when no signals are being transmitted, relay 17 is unoperated and the lower or receiving side of the four-wire circuit is completed through its contacts. The other side of the circuit at the same time is incomplete, since relay 16 is not operated and its contacts are open. Upon receipt of signals from line L_1, relay 3 is operated through amplifier-detector AD_1 connected across the receiving channel of the four-wire circuit, thus preventing the operation of relays 4, 16 and 17 and adapting the circuit for E—W transmission. When signals are transmitted in the opposite direction, relay 3 being unoperated, relays 4, 16 and 17 are energized. The operation of relay 4 reverses the polarity of the voltage applied to the line by battery B, while the operation of relays 16 and 17 completes the transmitting circuit and breaks the receiving circuit, respectively. A delay circuit 23 is introduced in the transmitting channel to allow for the time required for the operation of the several relays. As the operation of relay 4 is not instantaneous, a slight delay should be present in the speech circuit of the attended station so that the power reversal wave transmitted to the unattended repeater will precede the signal wave. To reduce the delay required a series resistor r shunted by condenser c may be included in the battery circuit. Series inductor l is optional.

In Fig. 2 there are shown repeaters which may be used where power is to be supplied over a signaling line to several repeaters connected in tandem. The circuits to be energized in repeater A are effectively in series with the upper side of the transmission line. Other repeaters of the same type may be connected in tandem with repeater A if the voltage supplied to the terminals of the line is increased to maintain the voltage across the several energy-absorbing circuits that are thereby connected in series. To complete the circuit, a conductive connection across the line is required at the end of the series of repeaters. This connection may be provided by terminating the series of type A repeaters with a repeater of the type shown in Fig. 1 or with one of the type represented at B in Fig. 2.

Repeater B of Fig. 2 is supplied with power from both of the attended stations between which it is located. The cathode circuit of one of the amplifying tubes and the anode circuit of the other amplifying tube are connected virtually across line L_2. The terminating connection required by the type A repeater is thus provided. The other cathode and anode circuits are similarly connected across line L_3.

The path of cathode heating current supplied to repeater A includes the upper side of line L_1, winding 24 of transformer T_1, the cathode heating elements of amplifier tubes V_1 and V_2, here shown connected in parallel, and winding 29 of transformer T_2, the upper side of line L_2, the terminating paths provided by repeater B, and the lower side of the transmission line. The cathode heaters are of high resistance; the voltage drop across them is substantially the same as the voltage applied to the anode of the amplifier tubes. The small voltage drop occurring in winding 24 of auto-transformer T_1 is applied as a grid bias to amplifier tube V_1 through windings 25 and 26 of the same transformer. The corresponding voltage drop in winding 29 of auto-transformer T_2 is similarly applied through windings 30 and 31 to the grid of amplifier tube V_2. The path of space current for amplifier tube V_2 may be traced from the upper side of line L_1, through winding 25 of transformer T_1, to the anode of the tube; from the cathode of that tube through winding 29 of transformer T_2 to the upper side of line L_2; whence the circuit is completed through the terminating paths of repeater B to the lower side of the transmission line. As repeater A is electrically symmetrical, the corresponding space current path of amplifier tube V_1 can readily be identified.

A high ratio of voltage transformation is realized when the transformers T_1 and T_2 serve as input transformers, and a lesser ratio when they serve as output transformers, by virtue of the three-winding construction shown. Windings 24 and 29, respectively, of these transformers are connected across lines L_1 and L_2, respectively, the signaling path of the first being completed through the series-connected condenser 32, and that of the second through the series-connected condenser 33. The direction of transmission may be controlled in the manner shown in Fig. 1. While one amplifier is operating, a negative voltage is applied to the anode of the oppositely directed amplifier. Reversing the polarity of the power source at the attended station reverses the conditions.

Referring now to the circuit of repeater B in detail, amplifier tubes V_3 and V_4 are arranged for transmission of signals in opposite directions. Filament current for the first tube passes from the source at the terminal or other attended station at the end of line L_1 through the upper side of line L_1, through repeater A and the upper side of line L_2, through winding 34 of auto-transformer T_3, through the filament of the tube and resistor 37 to the lower side of the line and back to the source. The filament circuit of the other tube, similarly, includes winding 39 of transformer T_4, resistor 38, a source of direct current applied to line L_3 at a distant attended station, and the circuits of any repeaters of the type A that may intervene. Space current for amplifier tube V_4 is supplied through the upper side of line L_2, winding 35 of transformer T_3, the discharge path of the tube, resistor 38, and the lower side of line L_1. Space current for amplifier tube V_3 is similarly supplied from line L_3.

When signals are to be transmitted from one station, the oppositely directed amplifier of the repeater is disabled by virtue of the polarity of the voltage applied to the signaling line at the distant receiving station. Any one of several methods may be used to provide the necessary cooperation between stations.

The voltage that must be applied to the transmission line when several repeaters of type A are connected in tandem obviously increases directly with the number of repeaters. By inserting a repeater of type B in the middle of a series of such repeaters and supplying the power required from both ends of the line, the voltage across the line may be considerably reduced and the possibility of injury to the insulation correspondingly reduced. From another aspect, greater efficiency and economy may be obtained as a result of the higher voltage made available at the repeaters, where the voltage applied to the line is fixed; or a greater number of repeaters may be connected in series.

The unattended repeater represented schematically in Fig. 3 differs from those hereinbefore described in that the circuits to be energized are connected virtually across the transmission line instead of in series with one side of it. Power may be supplied from either or both of the attended stations between which the repeater is located. This repeater has the advantage, therefore, that the power required for energizing it may be divided between the two attended stations and the power loss in the line thereby reduced. Where a number of such repeaters are connected in tandem a voltage only slightly less than that of the source is available at each.

The continuous direct-current path through the repeater includes only winding 50 of transformer T_1 and winding 58 of transformer T_2. Between the junction of these two windings and the lower side of the line is inserted the filament heating circuit, which includes, in series, choke coil 54, grid biasing resistor 55, the filament of amplifier tube V_1, resistor 56, the filament of amplifier tube V_2, and grid biasing resistor 57. For W—E transmission the respective upper sides of lines L_1 and L_2 are negative. Amplifier tube V_2 is then inoperative, since its filament is practically at the potential of the positive, lower side of the transmission system and its anode is connected through winding 51 of transformer T_1 and choke coil 54 to the negative side of the system. Amplifier tube V_1 at the same time is supplied with space current and thereby rendered operative. The space current circuit of tube V_1 may be traced from the positive, lower side of the line, through winding 59 of transformer T_2, the discharge path within the tube, resistor 55, choke coil 54, and either or both of the windings 50 and 58 depending on whether power is applied at one or both terminal stations, to the negative side of the source or sources of power. Space current for amplifier tube V_2 goes through a corresponding path when the polarity of the direct-current source is reversed.

Since the attenuation of the transmission line is less at low frequencies than at high frequencies an anti-resonant circuit comprising inductance 61 and condenser 62 may be connected in series with the line on each side of the repeater to provide equalization. An additional network may be incorporated in each amplifier to provide more accurate equalization. For this purpose there is shown connected across each of the discharge devices a parallel circuit comprising in one arm capacitance 76 and in series in the other arm, resistance 73, inductance 74 and capacitance 75. The repeater itself tends to discriminate against low frequency signals, first because of the inefficiency of the transformers at low frequencies, and second because of the filament and space current paths bridged across the line and by-passed by condenser 53. The low frequency signals are, to a certain extent, transmitted conductively from one line to the other through the series-connected windings **50** and **58**. By properly poling these windings and by use of additional phase adjusting networks as required the signals thus transmitted by conduction and the signals passed through the amplifier tubes are combined in phase. The repeating of low frequency waves is thereby improved. In many cases the equalizers may be dispensed with.

The repeater shown in Fig. 4 differs from the one just described in that the power currents are separated from the signaling currents before the transformers are reached. In this case the upper side of line L_1 is conductively connected with the upper side of line L_2 through the series-connected choke coils **64** and **65**. The filament and space current circuits are bridged from the junction of the two choke coils to the lower side of the transmission system. Condenser **67** shunting the latter circuit aids in the exclusion of high frequency signals from the conductive paths between lines L_1 and L_2.

In Fig. 5 is shown a full-duplex repeater that may be connected in tandem with others of the same type and supplied with power over either or both of the connected signaling lines. The battery supply may be connected, as shown, between ground and the mid-point of a choke coil **80** connected across the line at any suitable location, as at a terminal station. Substantially the full battery voltage is made available at the repeater by connecting a center-tapped choke coil **81** across the line.

The signaling circuits are similar to those in conventional types of full-duplex repeaters. Signals from line L_1 are passed from the balanced hybrid coil H_1 through series winding **82** to input transformer T_1 and space discharge device V_1. The amplified signals are then sent through output transformer T_2 to the bridged terminals of hybrid coil H_2 connected to line L_2. Signals from line L_2 are similarly passed in the opposite direction through space discharge device V_2. In this type of repeater both tubes are operative at the same time, anode potential being supplied to the two discharge devices through the primary windings of their respective output transformers and resistor **71**. The anode circuits are completed through the high resistance **84**, the filament of V_1, grid biasing resistor **83**, the filament of V_2, grid biasing resistance **85** and ground.

The circuits shown in Figs. 6 and 7 are especially adapted for connecting the head of a submarine cable to a terminal station, which may be several miles away. The signals received from the submarine cable are extremely minute. Great care must ordinarily be taken in shielding the connecting land line to prevent the masking of these weak signals by noise and interference from external sources. While it is usually impractical to install an attended repeater station with its associated local power supply unit at the cable head, an amplifier in accordance with the present invention may be installed at the cable head and supplied with power from the remote terminal station. As the outgoing signals are transmitted from the terminal station at high level it is unnecessary to provide a cable head amplifier for them.

In Fig. 6 transformer T_1 connects the submarine cable SC with the outgoing line L_2 from the terminal station. Through winding **102** of the transformer signals received from the cable are applied to the terminals of the cable-head amplifier tube V_1. The amplified signals are then conveyed to the terminal station through a transmission line L_1. Amplifier tube V_1 is energized from a battery B connected at the terminal station between ground and the mid-point of a choke coil **80** bridged across line L_1. The direct current passes over the conductors of line L_1 in parallel circuit to the mid-point of winding **108** of transformer T_2, where the current divides, one portion flowing through the resistor **105**, the filament of the amplifier tube, and grid biasing resistor **104** to ground, and the remainder passing through winding **107** of transformer T_1, the space discharge path of the amplifier and resistor **104** to ground. When signals are being sent out over the cable the amplifier is preferably rendered inoperative by reversing the polarity of the direct-current source. This feature, however, is not essential. A high resistance **103** is included in the input circuit of the amplifier to limit the flow of grid current which may occur during periods when the high level signals are being transmitted.

The circuit shown in Fig. 7 may be used where a three-conductor line connects the terminal station and the cable head. The circuit for transmitting current to energize the amplifiers comprises the central wire as one side and the two outer wires connected effectively in parallel as the other. Transformers T_2 and T_3 connected in the central wire serve to connect the cable head amplifier with the land line and the land line with the input of the terminal receiving circuit, respectively.

To cut out the repeater or amplifier of any of the circuits hereinbefore described in case of emergency, the arrangement shown in Fig. 8 may be used. If the filament of one of the amplifier tubes of the submarine cable repeater should burn out, for example, the cable would be useless unless means were provided for restoring the conductivity of the system. A switch **18**, which is restrained by a trigger **20** from closing under the action of spring **96**, is provided to establish a conductive connection from line L_1 to line L_2 when a sufficient voltage is applied to either of the coils **21**, **22** actuating the trigger. These coils are, as shown, connected across the respective filaments of the tubes V_1 and V_2. Ordinarily, the voltage across the filaments is insufficient to cause the trigger to operate; but upon failure of the filament the voltage rises and trigger **20** is attracted by the corresponding actuating coil. Alternatively, a fuse **97**, **98** may be connected in series with the respective filaments. By applying an excessive voltage at the terminal station the fuse may be melted and a sufficient voltage applied to the actuating coils to cause switch **18** to be closed.

The shunting effect of any element connected across the line in the repeater, as winding **7** and condenser **9** and winding **14** and condenser **15** respectively, can be eliminated by providing means for breaking the connections. A switch could not be used for this purpose, because contact noise, which would inevitably develop, would become intolerable. Preferably, means are provided for severing the conducting leads. Knife edges *a* and *b* operated from switch **18** and adapted to cut the shunting connections are represented in Fig. 8.

Where conditions require it, the repeaters can be sealed in armored pots suitable for use in exposed locations. For submarine locations the repeaters may be sealed in rugged, multiple-walled pots with soft wax or other padding forced under high pressure between the two outer walls.

Provision may be made for saturating the interior with chemically pure water to satisfy the affinity of the pot contents for water, thus reducing the likelihood of penetration of sea water.

While the present invention has been described with reference to several specific embodiments, other and widely different embodiments and applications of the invention will readily occur to those skilled in the art. The invention is therefore to be limited only by the spirit and scope of the appended claims.

What is claimed is:

1. A transmission system comprising a transmission line, amplifiers of the space discharge type at each of a plurality of intermediate, two-way repeated stations associated with said line, means to apply to said line waves to be repeated between successive sections of said line by said amplifiers, a source of direct-current power connected to said line at a distant station, means at said repeater stations for separating said waves and said power current and means for energizing said amplifiers with said separated power current.

2. A transmission system comprising a transmission line, thermionic amplifiers at a plurality of repeater stations associated with said line, means to apply to said line waves to be successively repeated from one section of said line into another by said amplifiers, means to transmit direct-current power over said line from a distant station to each of said repeater stations, and connections to said line at each of said repeater stations to divert said direct-current power to energize said respective amplifiers.

3. In a signaling system, a transmission line, a sending station including means to apply signaling waves to said line, a receiving station including a space discharge device, a source of power current reversibly connected to said line at said sending station, means at said receiving station to energize said discharge device with said power transmitted over said line, and means for reversing the polarity of the voltage applied to the discharge path of said device comprising signal-controlled means at said sending station for reversing the polarity of said source of power.

4. In a signaling system, a transmission line, a repeater station associated with said line, said repeater comprising two space discharge amplifiers adapted to repeat signals in respectively opposite directions through said line, and means at a point in said line remote from said repeater for selectively rendering said amplifiers operative, said means comprising a source of voltage, means for controlling the polarity thereof and means to apply said voltage to said line for transmission thereover to said repeater and the space current paths of said amplifiers.

5. In a signaling system, a transmission line, a repeater therein comprising two space discharge tube amplifiers adapted to transmit signals in respectively opposite directions, means to energize said amplifiers comprising a source of power current connected to said line at a point remote from said repeater, and means controlling the polarity of said source of power current for reversing the potentials applied to the elements of said space discharge amplifiers and thereby selectively to control the operativeness of said amplifiers.

6. In a signaling system, a transmission line, a pair of oppositely-directed vacuum tube amplifiers at a repeater station in said line, a source of direct current connected across said line at a distance from said repeater station, connections at said repeater for deriving space current from said source for one or the other of said vacuum tube amplifiers according to the polarity of said source, and means for controlling the polarity of said source in accordance with the direction of signals to be transmitted through said line.

7. In a signaling system, a transmission line, a terminal station and a plurality of tandem repeater stations associated with said line, each of said repeater stations including space discharge devices adapted to transmit signals in respectively opposite directions through said line, a source of voltage connected to said line at said terminal station, means to control the polarity of said voltage in accordance with the direction of signal transmission through said line, and means at each of said plurality of repeater stations for determining the operativeness of said discharge devices by the polarity of said voltage as applied to the discharge paths of said devices.

8. In a telephone system, a line, a speech repeater in said line comprising two space discharge amplifiers fixedly connected to said line to amplify in respectively opposite directions, and means at a remote point in said line controlled by speech waves transmitted thereover to apply over said line to said amplifiers a polarizing voltage rendering one or the other of said amplifiers exclusively operative according to the direction of speech transmission.

9. In a signaling system, a submarine cable, a repeater including a space discharge device at an intermediate point of said cable for amplifying signaling waves transmitted therethrough, and a source of power connected to said cable at a terminal thereof for transmitting current over the signaling system to provide energy for said repeater.

10. In a signaling system, a submarine cable, a source of power and a source of signaling waves connected to a terminal of said cable, a plurality of vacuum tube repeaters connected in tandem in said cable and adapted to amplify signaling waves transmitted therethrough, and connections at each of said repeaters for utilizing a portion of said power transmitted over the signaling system from said source to energize said vacuum tubes and for transmitting another portion of said power to a succeeding repeater over said cable.

11. In combination, a submarine cable, a terminal station therefor located at a distance from the head of said cable, an amplifier at the head of said cable adapted to amplify signals received over said cable, a transmission line connecting the output of said amplifier and said terminal station, and means for energizing said amplifier with power transmitted over said transmission line from said terminal station.

12. In combination, a submarine cable, a repeater located at the head thereof, a terminal station remote from said cable head, a transmission line between said terminal station and said repeater, said repeater being adapted to translate with low attenuation signals from said terminal station to said cable, and said repeater being further adapted to amplify signals received over said cable for transmission to said terminal station, and means for transmitting power from said terminal station over said line to energize the elements of said repeater.

13. In combination with a submarine cable and a terminal station remote from the head there-

of, an amplifier at said cable head adapted to amplify signals received over said cable, a receiving path connecting the output of said amplifier with said terminal station, a transmitting path for conveying signals from said terminal station to said cable head, means offering substantially no attenuation to signals for associating said transmitting path and said cable, and means for transmitting power from said terminal station over one of said paths to energize said amplifier.

14. In a transmission system, a transmission line, an amplifier of the space discharge type at an intermediate point of said line adapted to repeat from one section of said line to another waves transmitted therethrough, two sources of power current connected to said line at remote points on opposite sides of said amplifier, and connections to said line at said amplifier for deriving power from both of said sources to energize said amplifier.

15. In a signaling system, a transmission line, repeater amplifiers at a plurality of points in said line adapted to repeat signals from one section of said line to another, a source of power current connected to each of the terminals of said line for transmitting power over the signaling circuit, and means associated with each of said amplifiers for diverting transmitted power from said line to energize said amplifiers, the power required by said plurality of amplifiers being divided between said terminal sources.

16. In a transmission system, a transmission line, a series of repeaters in said line including space discharge devices, a source of power connected to said line at one terminal thereof, and a series connection of the discharge paths of a plurality of said discharge devices for energizing said series of repeaters from said source of power.

17. In a signaling system, a first transmission line, a terminal station at a distance from said line, a second transmission line connecting said first line and said terminal station, an amplifier located at the junction of said lines adapted to amplify signals transmitted from said first line to said second line, means for repeating signals from said second line to said first line without amplification, and means at said terminal station for controlling the operativeness of said amplifier in accordance with the direction of signal transmission.

18. In combination, a source of signaling waves, an amplifier connected to said source, said amplifier being relatively inefficient in a particular signaling frequency range, means for translating waves from said source without amplification and for combining them with waves from said amplifier, said translating means being relatively efficient in said particular frequency range, and said waves being combined in such phase relation as to compensate for the relative inefficiency of said amplifier in said particular frequency range.

19. In a signaling system, a transmission line, an amplifier at each of a plurality of repeater stations therein, said amplifiers being relatively inefficient at low signaling frequencies, means for transmitting power current over said line to energize a succession of said amplifiers, a path at each of said repeaters conveying power current and a portion of received signals around said amplifier, said path translating said low frequency signals with greater efficiency than high frequency signals and in such phase that low frequency signals from said amplifier are reinforced.

20. In a signaling system, a transmission line, an amplifier at a repeater station in said line, said amplifier being relatively inefficient at low signaling frequencies, means including an inductive element for translating direct current and low signaling frequencies around said amplifier, the signals thus translated being of such phase as to reinforce the signals from said amplifier.

21. A signaling system comprising a transmission line divided into a plurality of repeater sections, amplifiers for the two-way repeating of signals between successive ones of said sections, each of said amplifiers having a signal-responsive impedance-controlling element, means for transmitting power current over said line to said amplifiers, frequency selective means at said amplifiers for separating said power current and said signals, and means to energize said amplifiers with said separated power current.

22. A signaling system comprising a transmission line divided into a plurality of repeater sections, unilateral amplifiers for repeating signals from each of said line sections to a succeeding one, means for transmitting power current over said line to one of said amplifiers, frequency selective means at said one amplifier for separating said power current and signals, means to energize said amplifier with a portion of said separated power current, and means to apply the remainder of said power current to the succeeding line section for transmission thereover to a succeeding signal repeater.

23. In a signaling system, a transmission line, a repeater at an intermediate point thereof, said repeater comprising two signal amplifiers, means for transmitting power in one direction over said line to energize one of said amplifiers, and means for transmitting power in the opposite direction over said line to energize the other of said amplifiers.

24. In a signaling system, a transmission line, a plurality of signal repeaters intermediate the terminals of said line, said repeaters comprising thermionic amplifiers of the space discharge type, means for transmitting power in one direction over said line to energize the cathode heating and space path circuits of some of said amplifiers, and means for transmitting power in the opposite direction over said line to energize similarly others of said amplifiers.

15. In a signaling system, a transmission line, a repeater at an intermediate point thereof, said repeater comprising two oppositely directed signal amplifiers, means for transmitting power in one direction over said line to energize one of said amplifiers and in the opposite direction to energize the other of said amplifiers.

26. In a signaling system, a transmission line, a repeater at an intermediate point thereof, said repeater comprising two oppositely directed signal amplifiers of the space discharge type, and means for providing space current for said amplifiers comprising a source of direct current connected to said line at a remote point on each side of said repeater and respective series circuits each including one of said sources and the space current path of one of said amplifiers.

27. In combination, a transmission line, a signal repeater at an intermediate point thereof, said repeater including an amplifier of the grid-controlled space discharge type, and means supplying space current to said amplifier simultaneously from direct current sources connected to said line at remote points on opposite sides of said repeater.

28. In combination, a transmission line, a signal repeater at an intermediate point thereof, said repeater including an amplifier of the grid-controlled space discharge type, a source of direct current connected to said line at a remote point on each side of said repeater, a continuous direct current path extending through said repeater and between said sources, and connections at said repeater for deriving space current for said amplifier from both of said sources.

29. In combination, a transmission line, a signal repeater at an intermediate point thereof, said repeater including an amplifier of the grid-controlled space discharge type, a source of direct current connected to said line at a remote point on each side of said repeater, a conductive circuit comprising said line connecting said sources effectively in parallel with each other and the space current path of said amplifier.

30. In combination, two terminal stations, a plurality of conductors connected therebetween and carrying signal impulses, an unattended repeater station intermediate said terminal stations for the amplification of signals transmitted over said conductors, said repeater comprising one or more amplifiers of the space discharge type, two sources of power located at remote points on respectively opposite sides of said repeater, and means for transmitting power from both of said sources over said signal carrying conductors to said repeater, and means at said repeater for deriving space current for said amplifier or amplifiers from said transmitted power.

31. In a signaling system, a submarine cable, a submerged repeater including a thermionic device at an intermediate point of said cable for amplifying signal waves transmitted therethrough, said device having a heated cathode and a cathode-anode path, and means for supplying current over said cable for heating said cathode and energizing said cathode-anode path.

32. In a signaling system, a transmission line, an unattended signal repeater adapted to relay signals from one section of said line to another, said repeater comprising a space discharge amplifier having a thermionic cathode, and means to transmit power over said line from a point remote from said repeater to heat said cathode and to provide current for the space path of said amplifier.

33. In a signaling system, a transmission line, a signal repeater at an intermediate point thereof, said repeater including a space discharge amplifier tube, a source of direct current connected to said line at a terminal thereof, and a space current circuit comprising in series connection said source, the respective sides of said line and the discharge path of said tube.

34. In a signaling system, a transmission line, a space discharge amplifier for repeating signals from one section of said line to another, said amplifier having a thermionic cathode, and means for heating said cathode and providing space current for said amplifier comprising in series relation a source of direct current connected to said line at a point remote from said repeater, the respective sides of said line, and the space current and cathode heating circuit of said amplifier.

35. In a submarine cable system, a number of space discharge repeaters inserted in said cable at intervals along its length for amplifying signal impulses sent over said cable, and means to energize said repeaters by direct current sent over said cable, the path for said direct current being continuous through said repeaters and insulated from ground at all points between the terminals of said path.

36. In a submarine cable system, a plurality of space discharge repeaters inserted in said cable at intervals along its length for amplifying signal impulses sent over said cable, and means to energize said repeaters by direct current sent over said cable, the path for said direct current being continuous through said repeaters and comprising in series connection the space paths of a plurality of said repeaters.

37. In a signaling system, a transmission line, a repeater at an intermediate point in said line, said repeater comprising two signal amplifiers of the thermionic cathode type, and means for rendering said respective amplifiers alternatively operative comprising means for transmitting direct current over said line from a point remote from said repeater to energize one of said amplifiers, and means for reversing the polarity of said current to energize the other of said amplifiers.

38. In a signaling system, a transmission line, signal repeaters at a plurality of intermediate points in said line, said repeaters each including an amplifier of the space discharge type having a signal-responsive impedance-controlling element, and means to transmit power over said line from a point remote from said repeater to provide current for the space paths of said amplifiers.

39. A mid-line signal repeater, adapted to be supplied with power transmitted over the signaling line, comprising a pair of E terminals and a pair of W terminals, a pair of amplifiers, each comprising a space discharge device, fixedly connected in circuit between said pairs of terminals and adapted to repeat signals in respectively opposite directions of transmission therebetween, said repeater including a continuous circuit between said pairs of terminals for the transmission of direct current power through said repeater, and means for energizing said amplifiers with direct current power applied to said repeater at one or both of said pairs of terminals.

40. A repeater in accordance with claim 39 in which the space discharge path of at least one of said amplifiers is conductively connected between two of said terminals.

41. A repeater in accordance with claim 39 comprising an inductive element coupling both the input circuit of one of said amplifiers and the output circuit of the other to one of said pairs of terminals.

42. In a two-way repeater, a pair of amplifiers, each comprising a space discharge device having a cathode, an anode and a control electrode, fixedly connected in circuit to repeat signals in respectively opposite directions of transmission, conductive connections for supplying space current to said discharge devices from one or both of the signal circuit terminals of said repeater, and means for rendering said amplifiers alternatively operative comprising respective conductive connections from the anodes of said discharge devices to points that are of mutually opposite polarity with respect to the cathodes of said devices.

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