Oct. 30, 1951 J. E. BOUGHTWOOD ET AL 2,573,392

CARRIER TELEGRAPH SYSTEM

Filed April 22, 1947 5 Sheets-Sheet 1

FIG. 1

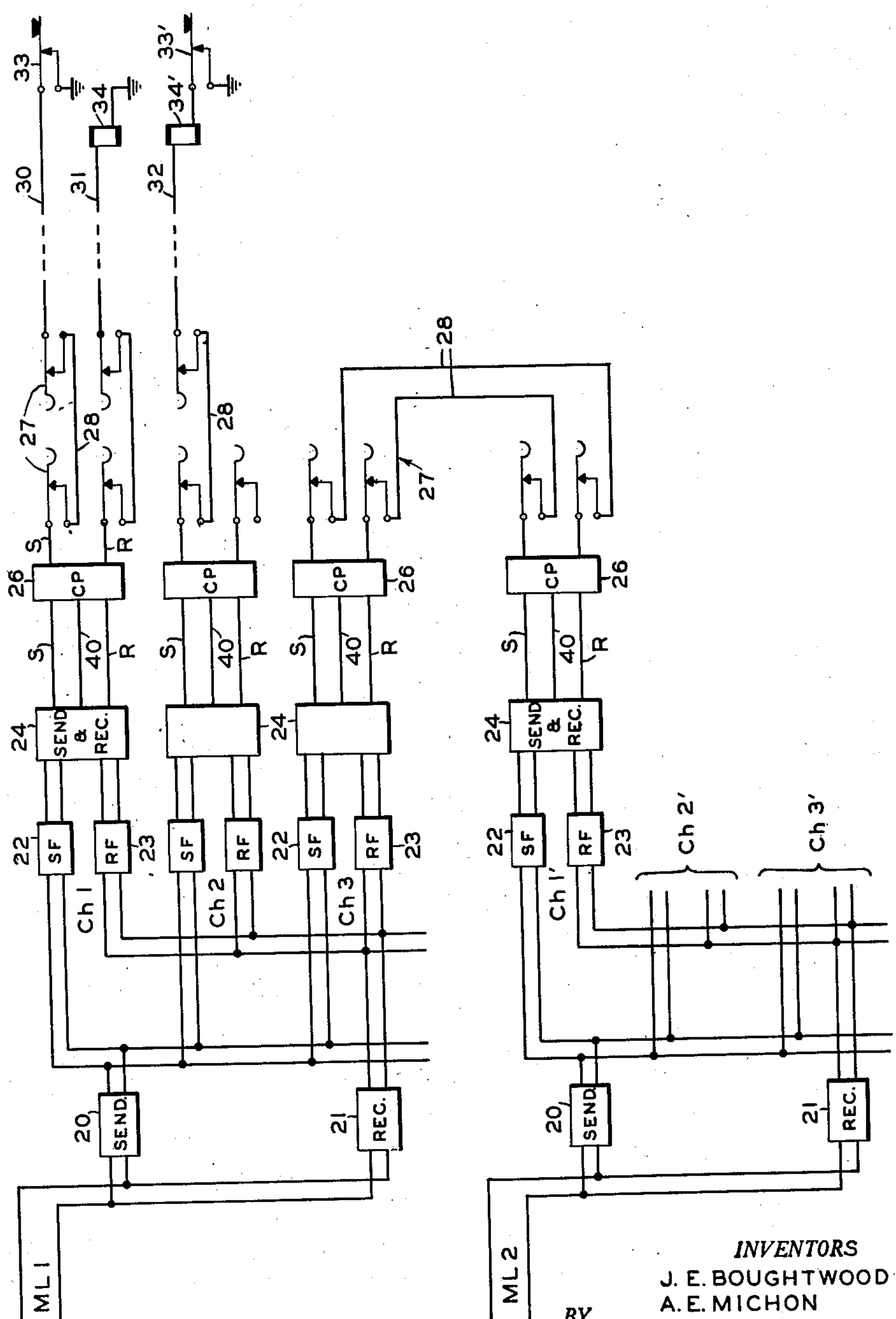

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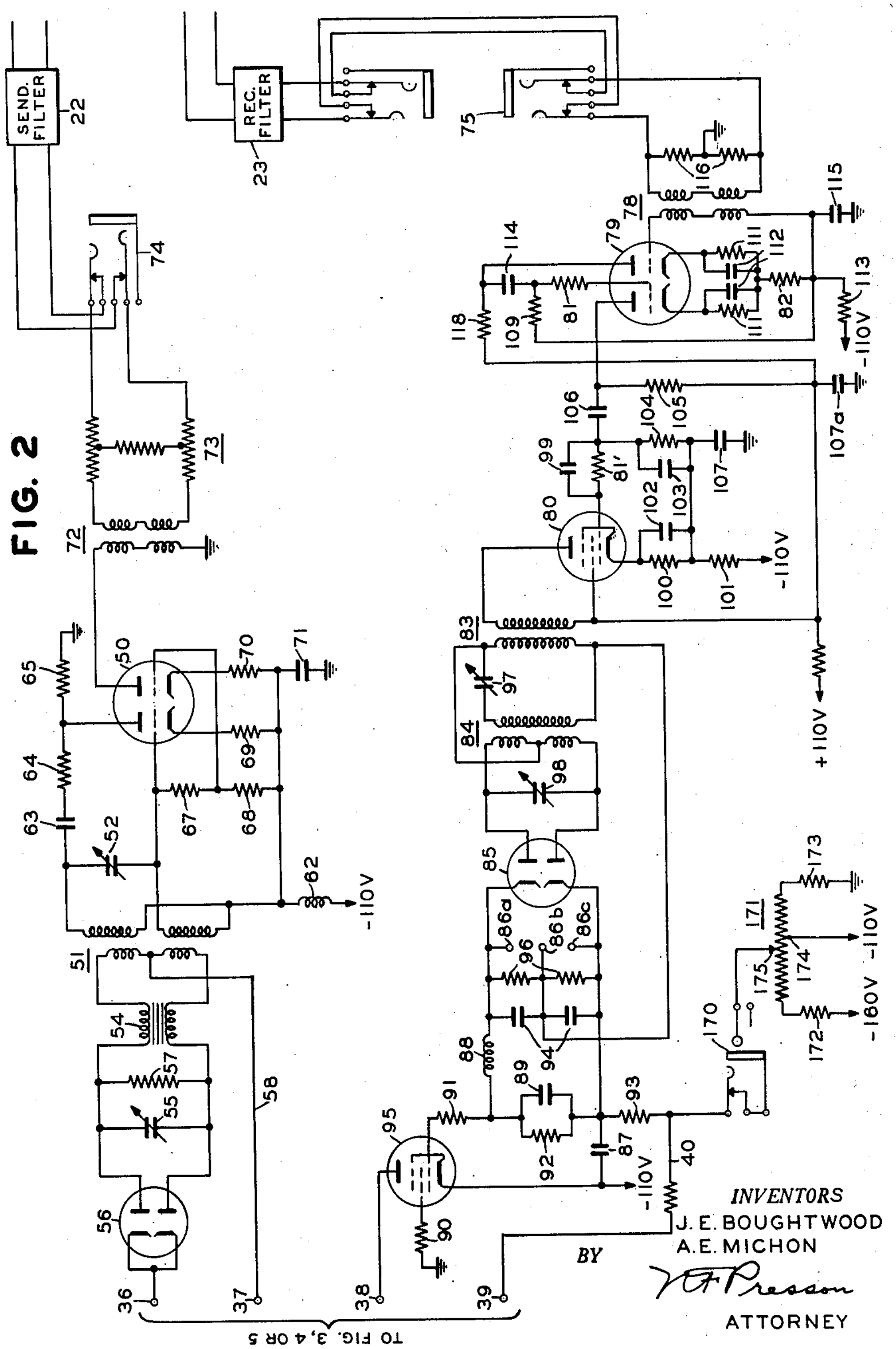
FIG. 2



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CARRIER TELEGRAPH SYSTEM

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FIG. 3

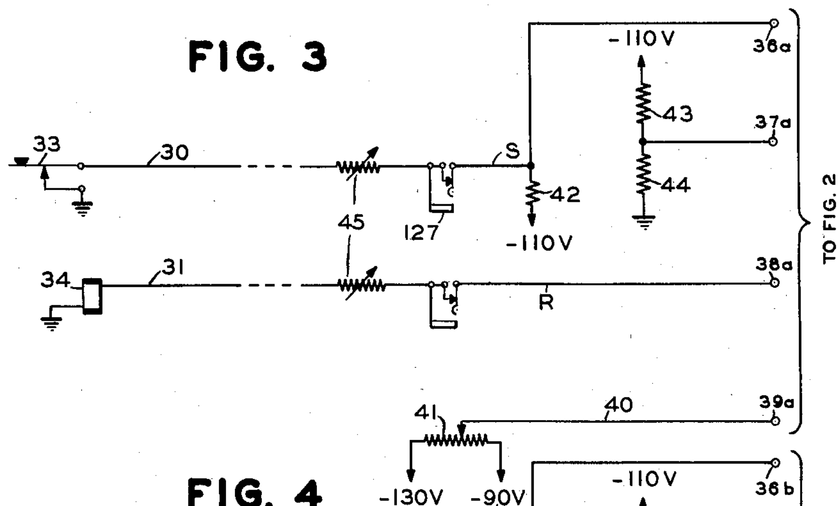


FIG. 4

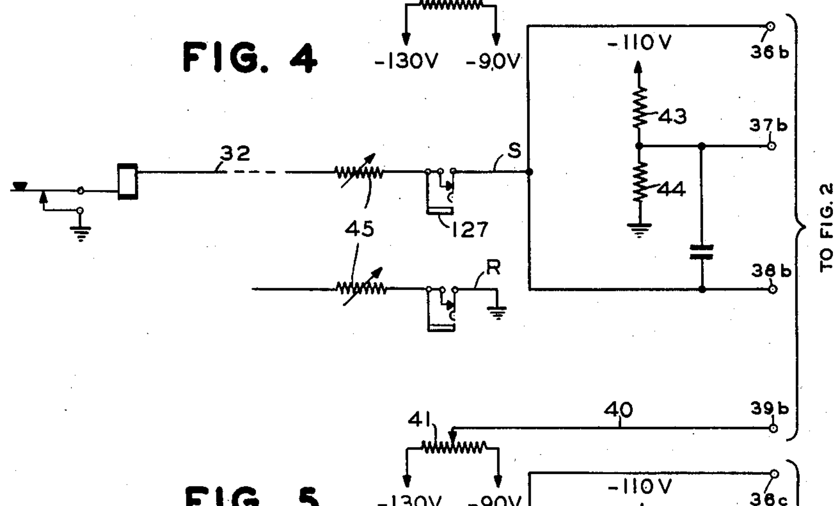
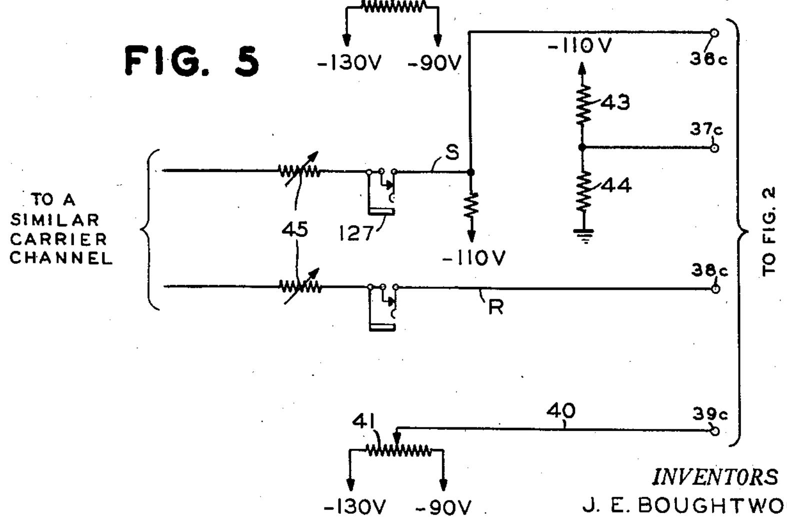


FIG. 5



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CARRIER TELEGRAPH SYSTEM

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FIG. 6

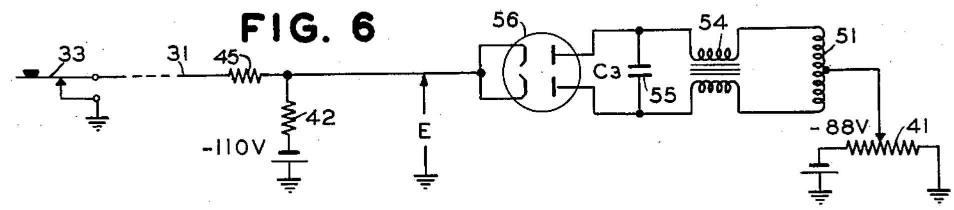


FIG. 7

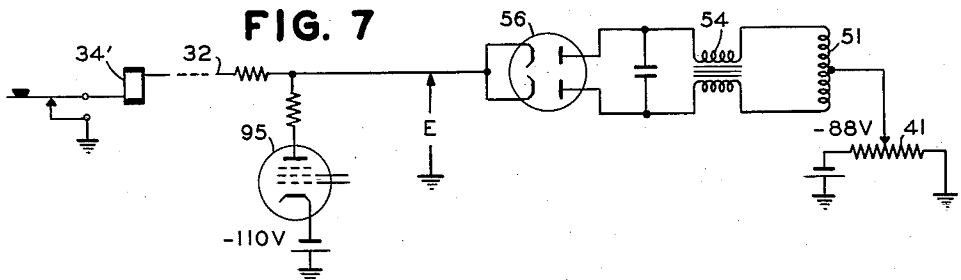


FIG. 8

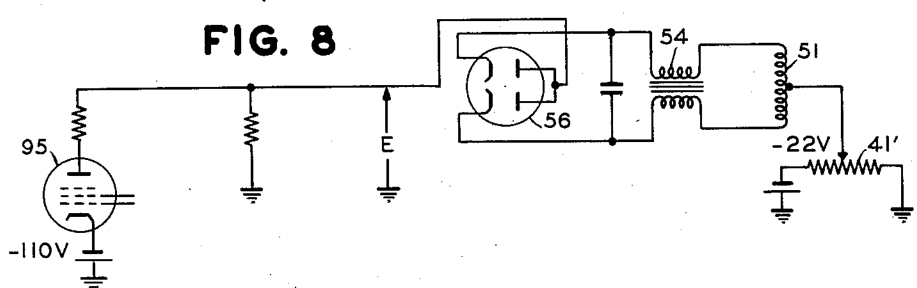
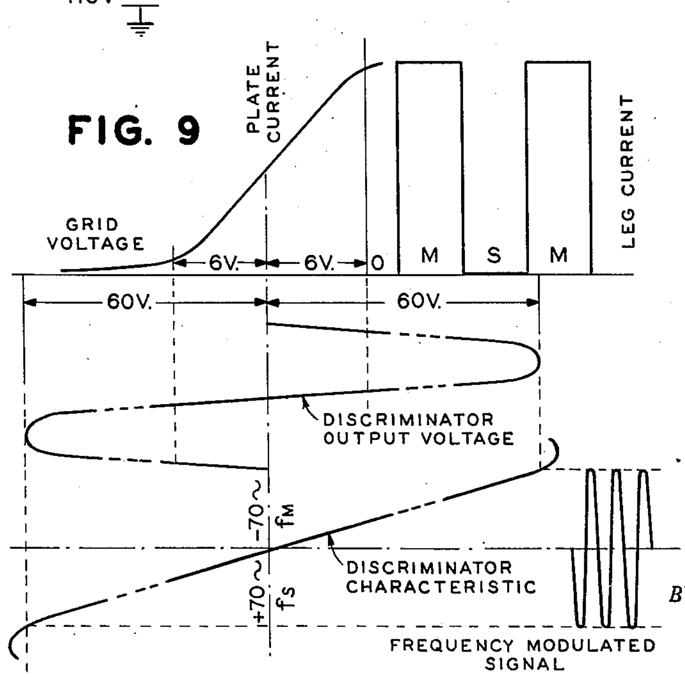


FIG. 9



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CARRIER TELEGRAPH SYSTEM

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FIG. 10

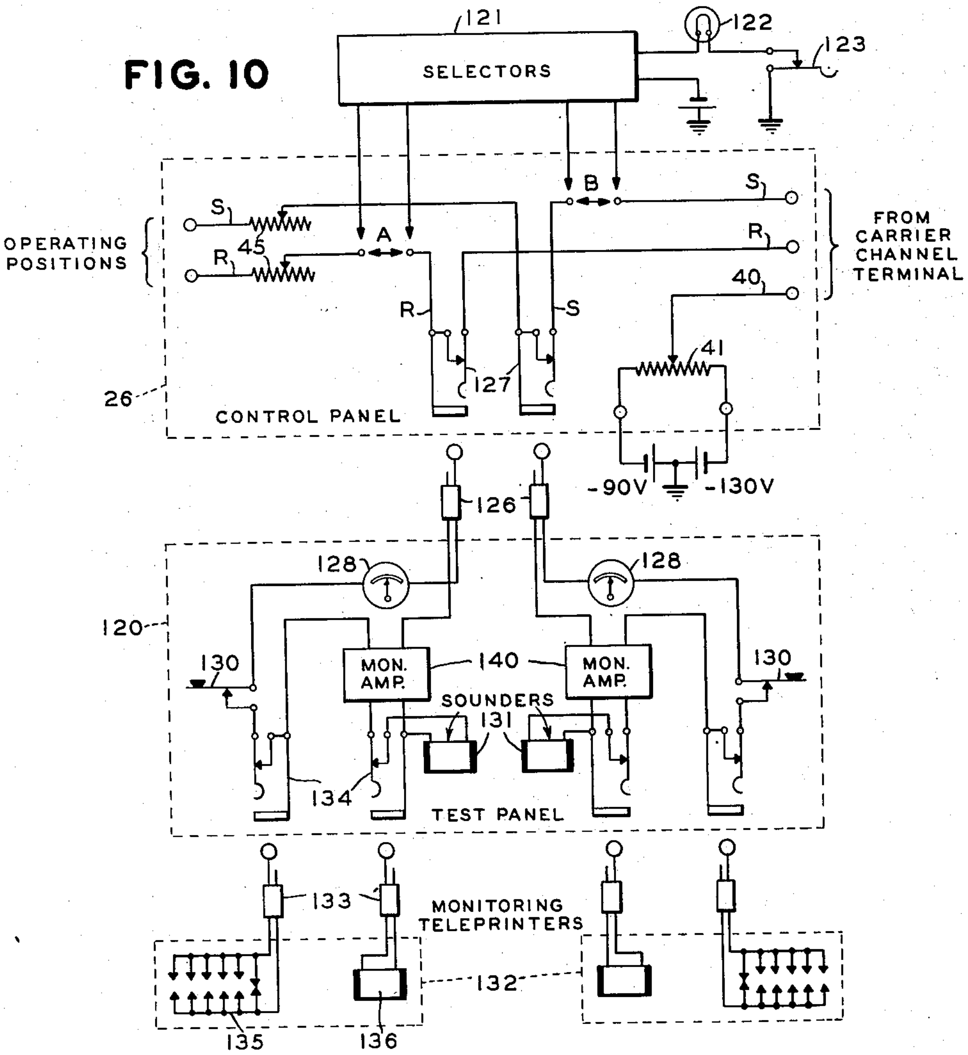
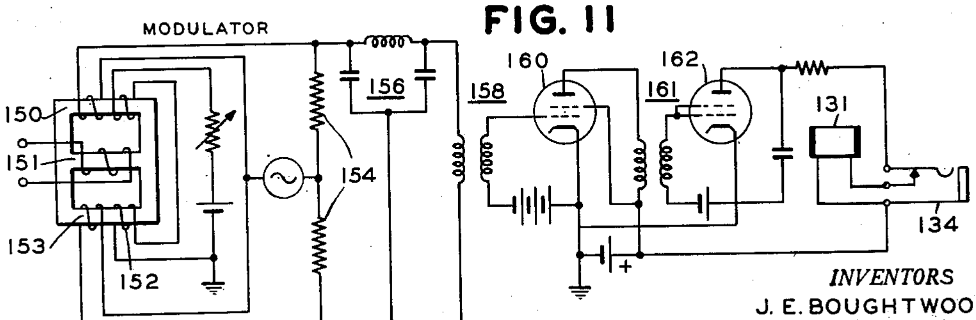


FIG. 11



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Patented Oct. 30, 1951 2,573,392

UNITED STATES PATENT OFFICE

2,573,392

CARRIER TELEGRAPH SYSTEM

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Application April 22, 1947, Serial No. 743,102

17 Claims. (Cl. 178—66)

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This invention relates to systems of transmission in which carrier currents are employed for the transmission of telegraph signals, and more particularly to improvements in polar carrier frequency systems in which separate frequencies respectively are utilized for the marking and spacing units of the permutation code telegraph signals. The term "polar carrier frequency system" is employed as a convenient expression for this type of carrier current telegraph transmission; such type of transmission is also often called frequency modulation or frequency shift modulation.

When the earlier Morse methods of handling and distributing telegraph services became inadequate, the demand for more channels was met by the application of multi-channel multiplex terminal sets of the time division type to the existing line wires. Messages handled over these channels were usually received at the multiplex terminal positions and were forwarded to delivery desks, or if destined for distant cities or for private wire patrons were manually retransmitted. The characteristics of single conductor ground return circuits soon fixed a limit to the speed and hence to the number of multiplex channels which the telegraph lines could accommodate. Additional increase in transmission capacity was obtained through the adoption of carrier current methods, but the carrier channels were at first designed to accommodate the high-speed multi-channel multiplex terminal sets then in general use. However, it is often preferred to handle telegraph services on a single channel basis, but the assignment of potential high-speed channels to slow-speed services was an inefficient use of the line capacity, and the devices for automatic retransmission of separate multiplex channels were costly and subject to operating difficulties. In addition, both the carrier and multiplex methods were subject to limitations and complications because of the necessity for accommodating the variety of patrons' circuits which were found in the wire plant, all necessitating somewhat different methods of operation.

The telegraph system disclosed herein provides for efficient utilization of each carrier channel, and the convenient establishment of individual circuits between ultimate operating

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positions or patrons. This is accomplished along with substantial economies in initial and operating costs, improvement in circuit margins, and prompt and efficient switching, testing and regulating service.

To efficiently utilize the line capacity, carrier systems are used in which the available frequency spectrum is first divided into two directional bands and these are further divided into smaller bands or "blocks" of suitable width, for example, of a width of 3000 cycles. Blocks of this width are of unique utility in that they will accommodate a single telephone circuit, a single high speed facsimile system circuit or two or more slow-speed facsimile circuits, or a multiplicity of telegraph circuits. Further, the telegraph channels may vary in band width depending upon the circuit speed to be handled; for example, channels for the high-speed multiplex circuits may be spaced at 300 cycle intervals, while channels for the slower speed teleprinters may be placed at 150 cycle intervals. Transmission over the telegraph channels is improved through the adoption of carrier terminal equipment as discussed herein. These carrier terminals embody frequency modulation, or polar carrier transmission, and transmission is direct thereby avoiding the use of relays at either the transmitter or receiver. Such terminals permit savings in initial cost and escape the relay maintenance costs.

Frequency modulation of the transmitter carrier is accomplished by raising the channel frequency, for example, 35 cycles above its mid-channel value to send a spacing signal and by depressing the frequency 35 cycles below its nominal value for the marking signal. The individual channels are given a band width of 80 cycles and are spaced at 150 cycle intervals in the spectrum. In practice, as many as 18 channels can be operated over a voice frequency transmission band approximately 3000 cycles wide.

With the number of channels thus greatly increased, a concentration of the positions for supervision of channel leg facilities, i. e., the connections to operating positions located in the main telegraph center or in the branch or patron's office, results in improved service and effects economies over the previous more or less individual handling of these facilities. As a means of simplifying this equipment and procedure, the different types of leg facilities which must be accommodated have been reduced to a minimum. Transmission quality over the main line carrier circuit is supervised by specialized attendants stationed at the main line terminals where they are aided by auxiliary communication circuits, automatic level regulators, wire trouble alarms, and the like, all directed to maintenance of a uniform continuous circuit quality for all channel groups of the main line circuits. Relieved of the necessity to supervise the main line circuits, an attendant then can supervise a large number of local leg circuits. Therefore, the sending and receiving legs for each channel preferably are carried through individual control panels which are grouped, or concentrated, in a carrier channel test board. At this test board the attendant may supervise the operation of each channel by means of common monitoring sets.

Each carrier terminal may be operated either as a duplex or a half duplex terminal, or by connection to the similar legs of another channel or circuit may serve as a repeater. In half duplex, transmission is obtained in either direction, but not in both directions simultaneously. The appropriate circuits for any of these three services may be selected either by switch means or by plug and jack connections which may be located either at the channel terminal or at the control panel.

The objects of the invention are as follows: To enable concentration of the leg circuits of a multiplicity of carrier telegraph circuits in a single non-operating supervisory position where normal testing and regulating functions may be performed, including the correction of bias in received signals and regulation of leg currents; to provide a carrier telegraph system which operates as a continuous electrical circuit between a primary sending instrument to a primary receiving instrument, without requiring relays; to provide a telegraph sending and receiving leg arrangement alternatively suitable for duplex, half duplex and repeater operation; to enable carrier telegraph circuits to be lined up between terminals and then cut through to operating positions while still under complete supervision and without any change in circuit margin; to provide carrier telegraph channels operated by single current sending and receiving legs and free of bias from operating position to operating position, and to enable repeater circuits to operate in this manner; to provide a leg circuit for an electronic telegraph transmitter which has low impedance to ground on open key to permit the discharge of induced interference currents; to provide a remotely controlled electronic keying circuit for an oscillator which is associated with the frequency determining circuit of the oscillator in such manner that all spurious effects are voided; to provide a telegraph sending leg and keying circuit which is substantially free of reactance in its terminal circuit and which has only a small amount of resistance; to provide a more suitable method of remote control of signal bias in a telegraph receiving circuit; to suppress interchannel telegraph interference more efficiently by means of rejector circuits; to provide an improved method of coupling a frequency modulation discriminator to a direct current telegraph transmitter; to provide more efficient amplification for direct current telegraph signals; and an

improved method of modulation for carrier current telegraph systems.

Further objects and advantages of the invention will be apparent from the following detailed description, taken in connection with the accompanying drawings showing one illustrative embodiment of the invention, in which:

Fig. 1 is a diagrammatic representation of main line terminal equipment of a frequency modulation carrier telegraph system embodying the features of the present invention;

Fig. 2 shows a sending and receiving circuit which is embodied in the terminal equipment of Fig. 1;

Fig. 3 shows a circuit arrangement used with the circuit of Fig. 2 when full duplex operation is desired;

Fig. 4 shows a circuit arrangement used with Fig. 2 when half duplex operation is desired;

Fig. 5 shows a circuit arrangement used with Fig. 2 when employed as a repeater;

Figs. 6, 7 and 8 explain the theory of operation of the sending leg circuit arrangements of Figs. 3, 4 and 5, respectively;

Fig. 9 shows the grid voltage-plate current characteristic of the output tube in conjunction with the translating characteristic of the frequency discriminator employed in the receiving circuit of Fig. 2;

Fig. 10 diagrammatically illustrates test panel and associated control panel circuits and equipment; and

Fig. 11 shows the circuit arrangement of one of the monitoring amplifiers diagrammatically depicted in Fig. 10.

The general features of a telegraph system embodying the principles of the present invention are diagrammatically illustrated in Fig. 1, which represents one terminal of such a system, the distant terminals being exactly or approximately similar thereto. For brevity only two of a possibly large number of main line circuits **ML1** and **ML2** entering a main office are shown, it being understood that the distant terminals of these circuits each lies in different cities. Each main line circuit may comprise one or more blocks or groups, each accommodating a multiplicity of channels, of which three are shown complete for circuit **ML1** and one for **ML2**. The rectangles **20** and **21** respectively represent the carrier main line sending and receiving terminals and are designated "Send" and "Rec" to indicate this. Such multi-channel terminals may be any of the conventional types known in the art, one of which is described in detail in papers by F. G. Bramhall and J. E. Boughtwood, published in the "Telegraph and Telephone Age" for the months of October and November 1942. The rectangles **20** and **21** contain the necessary equipment for sending and receiving blocks of carrier channels over a main line circuit and include such level regulating and supervisory equipment as is necessary or desirable to maintain the channels in satisfactory operating condition.

From the common buses at the carrier main line terminal, the carrier channels are connected through sending and receiving filters to the channel transmitting and receiving apparatus where the conversion from modulated carrier signals to direct current signals takes place and vice versa. As shown in Fig. 1, from the main line terminals **20** and **21**, the various sending and receiving channel pairs extend to channel terminal equipment which includes the vertical row of sending and receiving tuners or filters **22**, **23** and sending and receiving equipment diagrammatically indicated by the vertical row of rectangles 24. From the channel terminal equipment the sending and receiving leg circuits S and R extend through control panels CP diagrammatically shown by the vertical row of rectangles 26, to the loop switchboard which is indicated by various jacks 27 interconnected by conductors 28. At the loop switchboard the various leg circuit pairs may be connected over grounded circuits to operating positions either within the main office or at a distance therefrom, or they may be interconnected to form a channel repeater, for example, as shown for channels *Ch*3 and *Ch*1′. The channels *Ch*1, *Ch*3 and *Ch*1′ are shown as duplex circuits, while channel *Ch*2 is a half duplex circuit. A bias control conductor 40, the function of which will be described later, extends from each of the channel terminal sending and receiving devices 24 to the control panels 26.

From the loop switchboard comprising jacks 27, 28 and other equipment, the leg circuit pair of channel *Ch*1 is connected by means of conductors 30 and 31 to sending and receiving devices 33 and 34 respectively which may be located at a branch office or a patron's office. The element 33 is diagrammatically represented as a keying device for sending the code signals, but it will be understood that such a device may and usually will comprise the sending contacts in a telegraph printer, or the contacts in a transmitting distributor or other suitable means for sending the direct current marking and spacing code pulses comprising telegraph signals. Similarly, the element 34 is diagrammatically shown as a receiving magnet, but it will be understood that it may represent the receiving magnet of a telegraph receiving printer or other device suitable for receiving permutation code telegraph signals. The leg circuit *Ch*2 is connected by a conductor 32 to a receiving element 34′ and a keying device 33′ in series for half duplex operation.

The channel terminal of Fig. 2 is of the frequency modulated or polar carrier type disclosed in the patent to J. E. Boughtwood, No. 2,291,369, issued July 28, 1942, and possesses the advantages described in the patent, although the transmitter-receiver, or "transceiver," circuit of Fig. 2 differs from the patent in a number of important respects. In Fig. 2 the sending apparatus is shown in the upper half of the figure and the receiving apparatus in the lower half of the figure. The sending and receiving legs and two other conductors of the circuit have terminals 36 to 39, inclusive, which may be connected to corresponding terminals 36*a* to 39*a* of Fig. 3, 36*b* to 39*b* of Fig. 4, or 36*c* to 39*c* of Fig. 5, depending upon whether the circuit is to operate duplex, half duplex or as a repeater. The connections between these sets of terminals whereby the different modes of operation are established may comprise a multi-pole, multi-position switch, or plug and jack connections or other suitable cross-connection means known in the art. The control panel, which will be described in detail later, includes current regulating leg resistances, such as resistances 45 shown in Figs. 3 to 5, and a variable source of negative potential, such as is provided by a potentiometer 41, which is used for regulating, over the bias control conductor 40, the operation of the output tube 95 of the receiving side of Fig. 2. For convenience in understanding the action of the channel terminal, Figs. 3, 4 and 5 show simplified circuit diagrams of the leg connections when in the duplex, half duplex and repeater positions, respectively.

Referring to Figs. 2 and 3, the basic operation of the channel terminal will be described with particular reference to the conditions of duplex operation, i. e., the sending and receiving legs 30 and 31 extend separately to ground at the operating position. Considering first the upper half of the drawing of Fig. 2, the transmitter essentially comprises an oscillator triode directly coupled to an amplifying tube both of which conveniently may be provided by the two halves of a twin triode tube 50. For example, and by way of illustration only, a twin triode commonly designated in the art as a 12SN7 tube is suitable for this purpose. The oscillator, located at the left hand side of the twin triode, is of the conventional feed-back type but possesses certain important features designed to permit frequency modulation of its output by the telegraph signals. The tuning or frequency control circuit comprises in combination the parallel resonant circuit composed of the inductance of a transformer 51 and a condenser 52 which together are shunted by a coupled series resonant circuit comprising inductances 54 and a condenser 55. The condenser 55 is arranged to be short-circuited by the two halves in series of a double wave rectifier tube 56 under control of the sending leg. The tube 56 preferably, although not necessarily, is of the type known in the art as a 25Z6 rectifier. When condenser 55 is short-circuited by the rectifier tube 56, the inductances 54 and 51 combine to tune with condenser 52 to cause the oscillator to generate the frequency for a spacing signal S. For a marking signal M the rectifier 56 is open-circuited to introduce condenser 55 in circuit and to so shunt the parallel resonant circuit 51, 52 by the series resonant circuit 54, 55 as to cause the oscillator to generate a somewhat lower frequency. This combination of reactance elements also possesses a second and somewhat higher resonant frequency, but by designing the coils to have a more favorable reactance-resistance ratio at the designated marking and spacing frequencies, the tendency for the tube 50 to oscillate at a higher frequency is suppressed.

It will be appreciated that telegraphic modulation of the carrier oscillator may be obtained by swinging the oscillator frequency between two limiting values corresponding to the spacing and marking conditions, the frequency swing of the oscillator preferably being such as to give a modulation index of the order of 1. On circuits intended for start-stop printer operation, this swing between spacing and marking frequencies may, for example, be of the order of 70 cycles per second and for high speed 4 channel multiplex circuits may be twice that value. The oscillator output, after being amplified to the desired level by the directly coupled amplifier section of tube 50, passes through a transformer 72 and a resistance pad 73, and thence through a jack 74 and sending filter 22 to the sending bus of the main carrier terminal.

The manner in which the impedance of the rectifier 56 is varied by the telegraph signals in the sending leg to act as an open circuit or a closed circuit around the condenser 55 will be described with reference to Fig. 6. This figure discloses the essentials of the sending leg circuit for the duplex case, and the following table indicates the potentials which will be applied to the elements of the rectifier during the marking and spacing conditions of the key.

Signal	Frequency	Rectifier 56
M (marking)	lower	open.
S (spacing)	upper	closed.

Duplex Operation

Key	E	Sent Signal
	Volts	
M	−70	M
S	−100	S

The anodes of rectifier **56** are connected to a source of negative potential (indicated by the potentiometer **41** in Fig. 6) having a value of approximately 88 volts, and the cathodes of the rectifier are connected through a resistance **42** to a source of negative potential of approximately 110 volts, the leg circuit being connected between the cathodes and ground through a resistance **45** having a value such as to give a leg current of approximately 60 mils. With the transmitting key **33** closed to send a marking signal, the cathode potential stands at approximately −70 volts, thus making the anodes of the rectifier **56** more negative than the cathodes and imparting a high impedance to the rectifier to leave the condenser **55** effectively in circuit. The combination of elements **51**, **52**, **54** and **55** will now cause the oscillator to oscillate at the lower or marking frequency. When the key **33** is opened to send a spacing signal, the rectifier cathode potential will drop to approximately −100 volts to render the anodes less negative than the cathodes, at which time the rectifier will act as a low resistance shunt around the condenser **55**. This new tuning of the circuit will cause the oscillator to send the higher or spacing frequency. The amplitude of the oscillations generated under this condition is somewhat less than for the condition when the rectifier was effectively open; to equalize the two values, a resistance **57** of approximately 100,000 ohms is connected in shunt to the condenser **55**.

Fig. 7 discloses the circuit essentials, and the controlling potentials for the half duplex operation, the various values of which are shown in the following table:

Half duplex

Local Key	Distant Key	E	Sent Signal
		Volts	
M	M	−70	M
S	M	−100	S
M	S	0	M
S	S	0	M

In a half duplex operation the sending leg **32** serves for both sending and receiving from the operating position and is connected to both the sending and receiving sides of the carrier terminal, which connection is made at the rectifier cathodes. While the distant key (not shown) is closed to send a marking signal, tube **95** of the receiving side, which tube preferably is of the type known in the art as 25L6, presents a low resistance and the sending leg potentials then correspond closely to those for the duplex operation previously described for both the marking and spacing positions of the key. However, when the distant key is opened to send a spacing or a "break" signal, tube **95** presents a substantially infinite resistance and no current can flow in the sending leg from either source since the negative potential on the anodes of the diodes gives these tubes infinite resistance also. A spacing signal will now be received on the receiving leg, but the local oscillator continues to generate and send the frequency for marking.

If the local key is opened for the purpose of sending a spacing signal, a marking signal will still be sent since the key cannot secure control of the leg circuit which now in effect is standing open at the terminal in response to the open condition of the distant key. This inability to modulate the local oscillator when receiving a "break" signal corresponds to the usual half duplex practice. No lockup can occur since as soon as either key is closed, the distant end regains the power to send a marking signal.

Fig. 8 illustrates the condition which obtains when a receiving leg of a channel of one system, for example, *Ch***3** of ML**1** in Fig. 1, is connected to a sending leg of a channel of another system, such as *Ch***1**' of ML**2**, to provide direct repeating. In this case it is necessary to reverse the anode-cathode connections of the rectifier tube **56**, as shown in Fig. 8, and to provide a relatively low signal potential for the cathodes. The following table shows the various values of E in the figure, as follows:

Repeater

Received Signal	E	Sent Signal
	Volts	
M	−38	M
S	−10	S

For an incoming marking signal, the tube **95** will have low impedance and will cause the anodes of the rectifier **56** to be more negative than the cathodes, thus causing a marking signal to be generated and retransmitted. Conversely, an incoming spacing signal will impart a high impedance to tube **95** to cause the rectifier anodes to be less negative than the cathodes and hence generate a spacing signal.

The various potentials given in the foregoing three tables are representative of typical cases and are not critical but instead may vary over a considerable range. However, the relative potentials or polarities, as established between the anodes and cathodes of the rectifier **56** for the various circuit conditions, must be maintained as shown in order that the frequencies generated will correspond always to the marking and spacing conditions of the local key. The choice of the lower frequency for marking and the higher frequency for spacing corresponds to the conventional use in established systems but is otherwise entirely arbitrary; by a different choice of potentials and with the necessary circuit rearrangement, this allocation could be reversed.

The values of various of the condensers and resistors in the circuits of the twin triode tube **50** of Fig. 2 may be varied within reasonable limits. By way of example, suitable values are approximately as follows for the illustrative circuit shown: condensers **63** and **71** respectively are 0.1 and 20 mfd.; resistances **64** and **65** respectively are 27,000 and 39,000 ohms; resistor **67** is one megohm; resistor **68** is 240,000 ohms; resistance **69** is 1000 ohms; and resistance **70** is 300 ohms.

An important advantage of the frequency modulation circuit described above lies in the fact that the control or keying circuits, while effective to shift the frequency of the oscillator, are otherwise isolated therefrom. The two windings of the tuning and coupling transformer **51** are arcuately center-tapped and connected to different grounded circuits. Because of the differential connection of the left hand transformer windings along with the placement of the two windings of the inductance **54** on a common core, the sending leg encounters no inductance which would produce distortion. Another important advantage results from the fact that the circuit carrying the amplitude modulated signals is associated differentially with respect to the frequency-determining elements of the oscillator and so have no effect on these circuits other than the desired one of controlling the resistance across the pair of series connected rectifier elements. If this differential feature were lacking, the direct current telegraph signals would tend to cause spurious variations in the inductance of coils and transformers which would produce distortion in the generated signals, and such distortion would have to be corrected or avoided by a choice of oversized and expensive designs. Also, in non-differential arrangements, sharply modulated direct current signals passing over the sending leg would tend to cause transients in the oscillator tuning circuits which would be superimposed upon the marking and spacing frequencies in the form of an objectionable amplitude modulation.

The sending leg circuit above described also possesses a further advantage over the customary types of vacuum tube keying circuits. It will be noted that when sending a spacing signal, the rectifier **56** is conductive in all cases so that a relatively low resistance exists from the leg to ground through the rectifier and associated circuits. The differential connection, plus the low resistance, permit rapid discharge of the line capacity when the key is opened to send a spacing signal, and so avoid distortion from this cause. Also, induced charges picked up from other circuits, unless very large, flow to ground harmlessly. In vacuum tube keying circuits of the usual type, the keying circuit terminates in a high impedance grid circuit and so is subject to the development of high potentials from the charged line capacity, and from inductive interference, during the period when the key is open. Such stray potentials tend to send false signals, and are particularly troublesome on half duplex circuits.

Referring now to the receiving side of the circuit shown in the lower half of Fig. 2, the incoming frequency modulated carrier signals after being selected by the receiving filter **23** pass, through jacks **75** and a transformer **78**, to the limiting amplifier embodied in a twin triode tube **79** and to a tube **80**. This amplifier in its essentials is similar in some respects to that of Fig. 7 of the aforesaid Boughtwood Patent 2,291,369. Preferably, although not necessarily, tube **79** is of the type known in the art as 6SL7, and tube **80** is of the type known as 6SG7. The first section of the twin triode **79** amplifies the weak incoming signal to such an amplitude that continuous limiting can occur in the second section. Limiting here occurs on the negative half waves of the carrier current by virtue of the resistance **81** located in series with the grid of the second section of the twin triode, the value of the resistance preferably being of the order of 270,000 ohms. At the same time, by virtue of a common self-biasing resistance **82**, which may have a value of approximately 68 ohms, the second stage of the triode feeds back in phase to the first stage so that by regeneration a considerably enhanced gain is secured from the two stages in combination. The output of the second stage of tube **79** is applied to the third stage tube **80**, through a second 270,000 ohm grid resistance **81'** so that further limiting occurs, but on the half waves opposite from those cut off in the second stage. The signals are therefore symmetrically limited on both half waves. The three stage resistance-coupled regenerative amplifier now presents a greatly enlarged signal, symmetrically limited to constant level, to the output transformer **83**. While the first two stages employ an appreciable amount of regeneration, no instability results because in the frequency modulated signal, a positive signal either marking or spacing sufficient to maintain control is always impressed upon the input circuit. The limiting action helps to reduce the fortuitous signal distortion caused by noise and renders the received signal immune to the influence of variations in received level. The output of the limiter is made constant for input levels between −50 and +10 dbm.

From the output of the final amplifier stage **80**, the high voltage signals are impressed upon a balanced discriminator circuit which comprises transformers **83** and **84** with their associated capacities **97** and **98**, and a double diode tube **85**. The two branches of the network have amplitude frequency characteristics of opposite slopes. Their outputs are individually rectified in the diode and then differentially recombined. This discriminator is of the general type described in Seeley Patent No. 2,121,103, issued June 21, 1938, and serves to convert the incoming marking and spacing frequencies spaced apart, for example, 70 cycles, into D. C. potential reversals impressed across the terminals **86a** and **86c**. These potentials correspond to the single current signals originally transmitted over the distant sending leg circuit. The received signals as they appear at the terminal **86a** are in polar form with respect to the terminal **86c** and are so applied to the input circuit of the output pentode tube **95**, but after amplification they appear as single current signals in the receiving leg circuit.

The D. C. telegraph signals at terminal **86a** carry a superimposed carrier ripple, and in addition they may be subject to interchannel interference at frequencies of 80 and 150 cycles whose origin will be explained below. Interference suppression devices have therefore been included. The inductance **88** serves to suppress interfering frequencies of 150 cycles, and this inductance in conjunction with a condenser **89**, which preferably has a value of .02 mfg., further acts as a section of low-pass filter to provide some suppression for the 80 cycle and other high frequency interference. In view of the proximity of this latter region to the signal frequency, the interference suppression can not be complete, but if the channel band-pass receiving filters are of a sufficiently effective design the 150 cycles and higher frequency interference generally will be negligible.

In addition to removing the carrier, the low-pass filter is useful in minimizing the effect of the noise components whose frequencies lie outside the band assigned to the channel, and thus performs a function somewhat similar to that of the band-pass receiving filter, and consequently minimizes any interference from an adjacent channel which succeeds in getting through the band-pass filter and into the receiver. For a steady marking or spacing tone on the adjacent channel, the interference component in the received signal will either range between 80 and 150 cycles or between 150 and 220 cycles. These frequencies are sufficiently far above the 35 cycle maximum signaling speed that the low-pass filter can be designed to reduce the interference and still not introduce characteristic distortion.

The output tube **95** is one of a class which is particularly suited for operation in the position indicated. Its impedance is relatively low; moderate plate voltages are satisfactory; and a complete excursion from near zero plate current to predetermined maximum plate current can be obtained by a variation in grid potential of approximately 12 volts. Since the output voltage of the discriminator may be of the order of plus or minus 60 v., this voltage applied to the grid of the output tube serves to sharply swing its output current from zero (spacing) for negative grid to the desired maximum current value (marking) for positive grid. The tube is caused to limit or cut off at the desired marking current by means of the series grid resistance **91** which is of the order of one megohm.

It will be noted that the output tube **95** receives its space current from a —110 v. source connected to the cathode so that the plate may be connected directly to the grounded leg. Should any marking or spacing bias appear in the signals sent to the grounded leg, it may be corrected by adjustment of the grid bias of the output tube, using the bias control circuit **40** which extends to the control panel previously mentioned. At the control panel conductor **40** terminates in a potentiometer **41** which provides an adjustable potential ranging from —90 to —130 v. so that the mean grid bias value may be so adjusted as to equalize the spacing and marking lengths of the received signals.

For the convenience of maintenance men, there is provided a means for adjusting the bias on tube **95** at the amplifier position. This may comprise a jack **170**, Fig. 2, into which may be inserted a plug having the tip thereof connected to the adjustable slider arm of a potentiometer **171**. One end of the potentiometer is connected through a resistance **172** to a source of 160 v. negative potential; the other end of the potentiometer is connected through a resistance **173** to ground. The potentiometer affords an adjustment of the grid potential over a range of —130 v. to —90 v. A source of 110 v. negative potential is connected at **174** to the potentiometer, so that in effect the cathode of tube **95** is brought nearly to this point. The cathode of tube **95** is normally connected to a grounded 110 v. potential. Under certain operating conditions it will be necessary to make the grid of this tube considerably more negative than the cathode, and for this purpose the potentiometer **171** is connected to a grounded 160 v. telegraph battery. It is apparent however that that portion of the noise present in the 160 v. battery as represented by the IR drop across the potentiometer **171** between the point **175** and ground, in addition to the noise in the 110 v. cathode battery are all impressed on the grid of tube **95**, and this can be a cause of considerable signal distortion. As a means of substantially eliminating this noise a connection is made from the cathode battery to point **174** of the potentiometer **171**. Under this condition the only noise potential impressed upon the grid of the tube is that which occurs between points **174** and **175** of the potentiometer which as a practical matter will be negligible. It is to be understood that the potentiometer **171** performs the same function of eliminating signal bias as the potentiometers **41** of Figs. 3, 4 and 5, and preferably the potentiometers **41** are arranged in the same manner as potentiometer **171** and have the same potentials applied thereto, to minimize noise on the grids of the output tubes.

To further explain the operation of the receiving side of the system, including the high gain preamplifier, the discriminator and the high-gain, low-impedance output tube, reference is had to Fig. 9. This figure reproduces in somewhat idealized form the grid voltage-plate current characteristic of the output tube **95** in conjunction with the translating characteristic of the frequency discriminator. The high amplitude carrier signal changing rapidly in frequency between the spacing and marking values, when impressed upon the discriminator having a characteristic as shown in the figure, will produce output voltage reversals of as much as plus or minus 60 v. for application to the grid circuit of the output tube. As previously mentioned, and as indicated in the figure, the 25L6 tube requires a voltage of only about 12 v. to swing the grid from near cut-off on the negative side to positive cut-off, that is, a 12 v. input signal would suffice to change the plate or receiving leg current from spacing to marking. Consequently, an input wave whose voltage is of the order of ten times the tube cut-off voltage will produce an output wave of positive shape rising sharply from zero to a virtually square top. This signal shape is free from the transit time interval which is always present in circuits operated from the contacts of polar relays. As is well known, in single current circuits operated from such contacts a spacing bias arises since as the key is opened and closed, two transit time intervals are always added to each spacing signal but none to the marking signal. The fixed grid bias, provided that the incoming signals are free of bias, should be adjusted to be approximately centered on the tube characteristic, and in the present case would be about —6 v. with respect to the cathode.

In the foregoing description reference is made to various specific types of vacuum tubes serving various functions, and while these tubes are the preferred types of those presently available, the function of the circuits is not dependent on them; other tubes of somewhat similar characteristics may be satisfactorily substituted.

The values of the various condensers and resistors not heretofore specifically referred to, employed in the circuits of the receiving side of the system of Fig. 2 may be varied within reasonable limits. By way of example, suitable values are approximately as follows: condenser **87** is 1 mfd.; resistance **90** is 4000 ohms; resistance **92** is 270,000 ohms; resistance **93** is 47,000 ohms; condensers **94** are each .05 mfd.; resistances **96** are each 180,000 ohms; condenser **99** is .005 mfd.; resistance **100** is 1500 ohms; resistance **101** is 1000 ohms; condenser **102** is 1 mfd.; condenser **103** is .001 mfd.; resistance **104** is 270,000 ohms; resistance **105** is 220,000 ohms; condenser **106** is .01 mfd.; condensers **107** and **107a** are each 20 mfd.; resistance **108** is 220,000 ohms; resistance **109** is 470,000 ohms; resistances **111** are each 1000 ohms;

condensers 112 are each 1 mfd.; resistance 113 is 10,000 ohms; condenser 115 is 1 mfd.; and resistances 116 are each 300 ohms.

The combination of the transmitting and receiving circuits disclosed possesses important advantages, especially when used for duplex operation. It will be seen that in the sending circuit of Fig. 6 no relays are required and in fact the circuit is entirely resistive, except for the line capacity to ground. The signal distortion which would be caused by the inductance of relay windings, and the bias which would result from the use of relay type carrier modulators, are both absent. The frequency modulated carrier signals sent to line, therefore, are a perfect replica of the primary signals produced by the sending instrument, and since no dissymmetry is introduced by the receiving equipment, they will be so transmitted into the receiving leg. The normal signals are thus free of bias at all points in their transit and at no place does the circuit introduce a systematic bias which, if present, would subsequently have to be compensated by a systematic correction. This is of particular advantage on repeater circuits since it is not necessary for the attendant at any point on the circuit to allow a certain amount of bias to pass for the purpose of correcting a bias to be subsequently introduced as, for example, in receiving relays.

The remarks heretofore relative to distortion applied to a somewhat idealized case, but the situation is not substantially changed by the variations encountered in practice. For example, in the half duplex case, the inductance of the printer magnets in the sending leg will tend to introduce spacing bias in a manner well understood, and this bias will be further aggravated if two or more printers are included in the circuit. Bias may also arise should the leg circuit be long and composed of cable conductors with high capacity to ground, or of open wire with high leakage to ground. Such bias may be corrected at the transmitter by adjustment of the operating potentials applied to the rectifier 56, or a fixed adjustment which will give a mean minimum bias may be used.

Although the system regulating devices previously mentioned hold levels, frequencies and potentials within very close limits an individual control for each channel is provided to care for over-all adjustments. In addition to the cases already mentioned, signal bias may arise from slight variations in frequency of sending channel oscillators and of the oscillators which provide the translating frequencies in multi-channel systems. Some drift may occur in the discriminator tuning, or the grid or other tube operating potentials may vary. Also, regulating resistances for adjusting the current in the leg circuits are necessary.

Carrier channel test board

As hereinbefore stated, the control panels for observing the signals and adjusting the operation of the leg circuits of a large number of channels can be concentrated into small space, where they can be observed by one or two attendants, equipped with test and monitoring equipment. Fig. 10 indicates schematically the circuits of the control panel and the test panel. The control panel 26 contains certain of the equipment herebefore described in connection with Figs. 2 to 8, but with added provisions for the connection of selectors 121, which may comprise Gill selectors into the leg circuits. Such selectors and their method of operation are well-known in the art and hence are not disclosed here in detail. Normally the S and R leg circuits traverse the control panel with no means for indicating the quality of transmission, except as the attendant may make a routine observation or as he may be called in, over external facilities, by the operator at the channel operating positions. For this reason, where needed, selectors optionally may be connected into the circuits to permit convenient calling in of the test attendant from either the near or distant end of the circuit, the selectors having a signal lamp 122 and a push button 123. The selectors are particularly useful at the junction point where two channels are joined for repeating into each other, since they facilitate contacting the repeater attendant by means of the switching connections A and B, which connections may comprise either switches or plug and jack connections; the legs may be terminated in each direction at the control panel so that the attendant may converse in either direction independently of the other. This arrangement is particularly useful when lining up channels between terminals before the legs to operating positions are connected.

By means of the test panel equipment 120, which may readily be connected to any channel by means of the twin plugs 126 and jacks 127, the attendant may observe, by means of meters 128, the circuit bias and other signal characteristics on both the S and R legs. Also, he may communicate over the channel to the local operating positions or to the distant operating positions or test attendants by means of Morse keys 130 and sounders 131 or by means of the portable monitoring telegraph printers 132, which, by means of twin plugs 133 and jacks 134 may be connected into the circuit. In the telegraph printers the magnet 136 represents the receiving magnet of the printer, and the contacts 135 represent the transmitting contacts of the printer.

The swichboard assembly may be embodied in a cabinet structure designed to accommodate in its face as many as 16 or more control panels (32 channels) and two or more test panels within a space that can comfortably be covered by one or two attendants. Such a cabinet switchboard may be of the general type disclosed in Wood et al. Patent No. 2,009,978, issued July 30, 1935, but varied as needed to mount the present panels. The twin plugs, the telegraph instruments, and certain of the jacks previously mentioned are mounted in the key shelf, along with any other needed facilities. If warranted, the key shelf may be arranged to accommodate one or two teleprinters 132 or these machines may be mounted on a suitable wheeled table whereby they can be moved along a row of such switchboard sections as needed. Obviously, several such switchboard sections may be mounted contiguously so that a considerable number of channels may be handled by a small number of attendants, using a minimum amount of testing equipment.

Monitoring amplifier

Monitoring sounders or teleprinters possess appreciable resistance, and ordinarily their random insertion into critically adjusted leg circuits will reduce the current and introduce bias. This objection is overcome in the test panel herein described, through the use of a novel monitoring amplifier. Requirements of this amplifier are quite rigorous in that it must not only amplify D. C. telegraph signals, irrespective of the direction of current flow, so faithfully that printing ranges as measured on the monitoring teleprinter will correspond substantially exactly to the ranges measured on the patron's machine, but introduction of the monitoring teleprinter into the leg circuit will not alter or impair the transmission properties of the circuit. This latter requirement is particularly important where a number of monitoring teleprinters are used in a single circuit and which tend to cause a considerable cumulative loss. The amplifier disclosed herein meets the above requirements in that the signals are amplified virtually without distortion and the input resistance is very low. At the same time, the device is simple and inexpensive and is free of the critical adjustments which usually characterize direct current amplifiers. Another advantage is that this amplifier may be operated with grounded batteries although the input connects to an ungrounded point in the D. C. leg circuit.

The monitoring amplifier, whose circuit is shown in Fig. 11, comprises three units: a linear modulator, a linear amplifier and a linear detector. The modulator, shown in the left-hand portion of the figure, comprises an iron core 150 having two outer balanced legs and a central leg. An input winding 151, which may have a resistance of the order of 5 ohms, is wound upon the central leg of the core, while upon the two outer legs a D. C. biasing winding 152 and a carrier winding 153 are each symmetrically disposed. This coil, along with an associated center tapped resistance 154, constitutes a Wheatstone bridge which in the absence of current in the input winding 151 is perfectly balanced so that no voltage is impressed upon the input of the amplifier stage. However, the two coils of the bias winding 152 are in series aiding on the two outer legs of the core to produce a fixed magnetic flux passing in series around the outer legs of the core. The bias current is adjusted to cause approximate saturation of this path through the outer legs so that the two bridge windings are substantially non-inductive. When signal current flows through the input winding, a flux originating in the central leg of the core will pass in parallel direction through the two outer legs to add to the bias flux in one leg and to oppose it in the other leg. In the leg where the fluxes add, the signal will have only the negligible effect of slightly extending the degree of saturation, so that the bridge winding on this leg continues to be non-inductive. In the other leg, however, the signal flux, which approximates the bias flux, will reduce the residual flux to zero and the bridge winding on this leg will be highly inductive. Under this condition, the bridge bears a maximum of unbalance, and a maximum carrier voltage will be impressed upon the amplifier stage. It should be noted that the bridge coil functions to produce an unbalance current whatever the direction of signal flow in the input circuit, although the unbalance is in a different sense. Since the sense of the unbalance is immaterial in this case, the operation of the amplifier and its associated teleprinter are independent of the direction of current flow just as if the teleprinter were inserted directly into the leg circuit. Since the saturated coil is a source of abundant harmonics, a low-pass filter 156 is inserted to suppress these and to limit the bridge operation to the fundamental carrier frequency.

The signal modulated carrier from the unbalanced bridge, bearing an envelope which is a close replica of the original D. C. signal, is applied through a transformer 158 to the amplifier stage 160 and thence through transformer 161 to the detector 162. Both the amplifier and detector tubes and associated circuits are chosen to be substantially distortionless and to apply a final signal to the teleprinter which will produce the same printing range as is obtained on the patron's teleprinter even in the absence of the monitoring teleprinter. It is, of course, assumed that there is no substantial distortion introduced into the leg circuit by line capacity or other line characteristics intermediate the monitor and patron's teleprinter.

The resistance of ordinary teleprinter magnets, such as the magnet indicated at 136, is usually about 250 ohms, with an inductance of about 3 henries. If but one monitoring teleprinter is inserted in any one leg circuit, usually the effect upon the circuit will be within tolerable limits, but if several receiving magnets are inserted into a leg circuit they would obviously have a profound effect upon the signaling properties of the circuit particularly where the leg circuits are electronically operated as in the terminal herein described, and telegraph sounders have a similar effect. By means of the monitoring amplifiers having input resistances of only 5 ohms and inductances of 0.1 henry, several teleprinters or sounders may be inserted in series in the leg circuits with no discernible effect upon the signal quality.

As indicated in Fig. 1, the S and R legs of the carrier channels follow the standard practice of terminating at a loop switchboard, where also are terminated the leg circuits to operating positions located either in the local office or branch or patron's offices. At this point, the channels may be either permanently assigned or temporarily connected to any particular operating position, or channels of one circuit may be connected to channels of other circuits for repeating purposes. It is sometimes desirable or necessary to insert monitoring teleprinters or sounders in circuit at this point, and these preferably should be provided with monitoring amplifiers of the type described above.

The improved system disclosed herein has been described in connection with a frequency modulated carrier telegraph channel which has the advantage of completely electronic leg or loop circuits, that is, the leg circuits contain no electromechanical devices other than the subscribers' or operators' sending and receiving instruments, which instruments may comprise facsimile or other types of cooperating sending and receiving devices used in the communication and signaling art for various purposes. Since these electronic circuits are substantially free of inertia or other factors which would cause distortion they may be used for handling signals of much higher primary frequency than those illustrated. For example, the channels may handle facsimile signals having an interruption rate of 1000 per second or higher to swing the frequency of the oscillator between two frequencies spaced 2000 cycles apart to give a suitable deviation ratio. Various other transmission speeds, of course, may be employed. The rectifiers 56 are illustrated as of the thermionic type, but any other suitable type of rectifier or equivalent device may be used, for example, copper oxide, selenium, silicon and germanium types.

For brevity in the specification and claims, the term "rectifier" is employed in a generic sense to define a device which readily permits current to flow in one direction but which exhibits a very high resistance or an open-circuit condition to current flow in the opposite direction; the term "telegraph" is employed generically to define all systems for electrically transmitting, receiving or reproducing information by coded signals and also includes facsimile; and the terms "marking" and "spacing" signals include those differentiated by different electrical signaling conditions such as different signal levels, current and non-current flow, polar signals and different frequencies.

Various modifications of the apparatus and circuit arrangements shown, and various equivalents or substitutes for the devices illustrated, readily will occur to those versed in the art without departing from the spirit or scope of the present invention. The disclosure, therefore, is for the purpose of illustrating the principles of the invention which is not to be regarded as limited except as indicated by the scope of the appended claims.

We claim:

1. In a carrier current telegraph transmitting system, an oscillator having a frequency-determining circuit, means for shifting the oscillator frequency comprising a resonant circuit operatively included in said frequency-determining circuit and including two impedances selectively effective to tune said frequency-determining circuit to at least two different frequencies, a potential-controlled rectifier connected in shunt to one of said impedances whereby the said impedance is short-circuited by the rectifier when it is conducting thereby to tune said circuit to one of said frequencies but is effectively in circuit when the rectifier is not conducting thereby to tune said circuit to another of said frequencies, and signal generating means for applying different control potentials to the electrodes of said rectifier to cause it to be conducting and non-conducting alternately to produce spacing and marking carrier telegraph signals by increasing and decreasing the oscillator frequency to cause the oscillator to generate said two different frequencies respectively.

2. In a carrier current telegraph transmitting system, an oscillator having a frequency-determining circuit, means for shifting the oscillator frequency comprising a resonant circuit operatively included in said frequency-determining circuit and including two impedances selectively effective to tune said frequency-determining circuit to at leaset two different frequencies, a potential-controlled rectifier connected in shunt to one of said impedances and in series with the other impedance whereby the one impedance is short-circuited by the rectifier when it is conducting thereby to tune said circuit to one of said frequencies but is effectively in circuit when the rectifier is not conducting thereby to tune said circuit to another of said frequencies, and signal generating means for applying different control potentials to the electrodes of said rectifier to cause it to be conducting and non-conducting alternately to produce spacing and marking carrier telegraph signals by increasing and decreasing the oscillator frequency to cause the oscillator to generate said two different frequencies respectively.

3. In a carrier current telegraph transmitting system, an oscillator having a natural frequency determined by a frequency-determining circuit, means for shifting the oscillator frequency circuit comprising a condenser operatively connected to the said frequency-determining circuit, a potential-controlled rectifier connected in shunt to said condenser whereby the condenser is short-circuited by the rectifier when it is conducting thereby to tune said circuit to one of said frequencies but is effectively in circuit when the rectifier is not conducting thereby to tune said circuit to another of said frequencies, and signal generating means for applying different control potentials to the electrodes of said rectifier to cause it to be conducting and non-conducting alternately to produce spacing and marking carrier telegraph signals by changing the oscillator frequency to cause the oscillator to generate said two different frequencies respectively.

4. In a telegraph carrier wave transmission channel, an oscillator adapted to generate a carrier current of a frequency as determined by a frequency-determining circuit potential-controlled rectifier means having anode and cathode elements collectively comprising two main electrodes of the same polarity and at least one main electrode of the opposite polarity thereby to form two current paths through the rectifier means when conducting, an auxiliary circuit including a reactance arranged to be selectively associated with said frequency-determining circuit in accordance with the conducting or non-conducting condition of the potential-controlled rectifier means for the purpose of shifting the frequency of said oscillator upward or downward to produce spacing or marking polar carrier signals, a source of potential for applying a biasing voltage to at least one side of said rectifier means, a source of direct current marking and spacing signals, said source of direct current marking and spacing signals being connected to one side of said rectifier means in series-parallel circuit with said two current paths through the rectifier means and in shunt with the source of biasing potential therefor and providing direct control of the rectifier means by said direct current marking and spacing signals.

5. In a telegraph carrier wave transmission channel, an oscillator adapted to generate a carrier current of a frequency as determined by a frequency-determining circuit potential-controlled rectifier means having anode and cathode elements collectively comprising two main electrodes of the same polarity and at least one main electrode of the opposite polarity thereby to form two current paths through the rectifier means when conducting, an auxiliary circuit including a reactance arranged to be selectively associated with said frequency-determining circuit in accordance with the conducting or non-conducting condition of the potential-controlled rectifier means for the purpose of shifting the frequency of said oscillator upward or downward to produce spacing or marking polar carrier signals, the two sides of said auxiliary circuit being connected respectively to said two main electrodes of the same polarity, two sources of potential for applying different biasing voltages respectively to opposite sides of said rectifier means, a source of direct current marking and spacing signals, said source of direct current marking and spacing signals being connected to one side of said rectifier means and in shunt with the source of biasing potential therefor and providing direct control of the rectifier means by said direct current marking and spacing signals.

6. In a telegraph carrier wave transmission

channel, an oscillator adapted to generate a carrier current of a frequency as determined by a frequency - determining circuit potential-controlled rectifier means having anode and cathode elements collectively comprising two main electrodes of the same polarity and at least one main electrode of the opposite polarity thereby to form two current paths through the rectifier means when conducting, an auxiliary circuit including a reactance arranged to be selectively associated with said frequency-determining circuit in accordance with the conducting or non-conducting condition of the potential-controlled rectifier means for the purpose of shifting the frequency of said oscillator upward or downward to produce spacing or marking polar carrier signals, the two sides of said auxiliary circuit being connected respectively to said two main electrodes of the same polarity, two sources of potential for applying negative biasing voltages of different values respectively to the anode and cathode structures of said rectifier means, a source of direct current marking and spacing signals, said source of direct current marking and spacing signals being connected to the cathode structure of said rectifier means in series-parallel circuit with said two current paths through the rectifier means and in shunt with the source of negative biasing potential for said cathode structure and providing direct control of the rectifier means by said direct current marking and spacing signals.

7. A network including a plurality of reactance elements for tuning the network to at least two different frequencies, a potential-controlled variable resistance element in circuit with said reactances for selectively controlling their tuning characteristics, means for applying to said network a source of control potential for said resistance element, said reactance elements each being connected differentially with respect to the circuit for said control potential substantially to prevent any direct influence on the reactance elements by the current which flows in response to the control potential.

8. A network including a plurality of reactance elements for tuning the network to at least two different frequencies, a potential-controlled variable resistance element in circuit with said reactances for selectively controlling their tuning characteristics, said network having an electrical mid-point, and means for applying a source of control potential for said resistance element to said electrical mid-point substantially to prevent any direct influence on the reactance elements by the current which flows in response to the control potential.

9. A network including a plurality of reactance elements including an inductance element in which the inductance of the element is variable depending upon the flow of current therethrough, for tuning the network to at least two different frequencies, a potential-controlled variable resistance element in circuit with said reactance elements for selectively controlling their tuning characteristics, means for applying to said network a source of control potential for said resistance element, said inductance element being connected differentially with respect to the circuit for said control potential substantially to prevent any direct influence on the inductance element by the current which flows in response to the control potential.

10. In a carrier current telegraph transmission system in which the frequency of an oscillator is shifted between two limiting values to produce spacing or marking polar carrier signals by means of a resonant circuit whose reactive characteristic is determined by a potential-controlled rectifier in accordance with direct current spacing and marking signals, means for preventing the amplitude-modulated direct current signals from detrimentally affecting the oscillator tuning circuit, which comprises circuit connections for causing any direct current flowing through the rectifier when it is conducting to flow differentially in both sides of said resonant circuit between the electrical mid-point of the circuit and said rectifier thereby to neutralize any spurious inductive effects of said direct current upon said resonant circuit.

11. In a carrier current telegraph transmission channel, an oscillator adapted to generate a carrier current of a frequency as determined by a frequency-determining circuit, means for shifting the oscillator frequency comprising a resonant circuit including inductive reactance, capacitive reactance and a potential-controlled rectifier for determining the reactive characteristics of the circuit in accordance with the conductive or non-conductive condition of said rectifier, impedance coupling means included in said frequency-determining circuit, a source of direct current spacing and marking signals for controlling said rectifier to cause it to be conducting and non-conducting alternately to produce spacing and marking polar carrier telegraph signals, and means to prevent the amplitude-modulated direct current signals from detrimentally affecting the oscillator tuning circuit comprising a source of rectifier control potential connected to the electrical mid-point of said impedance coupling means to cause any direct current flowing through the rectifier when it is conducting to flow differentially with respect to said inductive reactance.

12. In a carrier current telegraph transmission channel, an oscillator adapted to generate a carrier current of a frequency as determined by a frequency-determining circuit, means for shifting the oscillator frequency comprising a resonant circuit including inductive reactance, capacitive reactance and a potential-controlled rectifier for determining the reactive characteristic of the circuit in accordance with the conductive or non-conductive condition of said rectifier, impedance coupling means included in said frequency-determining circuit, a source of direct current spacing and marking signals for controlling said rectifier to cause it to be conducting and non-conducting alternately to produce spacing and marking carrier telegraph signals, and means to prevent the amplitude-modulated direct current signals from detrimentally affecting the oscillator tuning circuit comprising a source of rectifier control potential connected to the electrical mid-point of said impedance coupling means to cause any direct current flowing through the rectifier when it is conducting to flow differentially with respect to said inductive reactance, and another impedance bridged across said resonant circuit to equalize substantially the amplitudes of the spacing and marking carrier signals.

13. In a carrier wave transmission channel, an oscillator adapted to generate a carrier current of a frequency as determined by a frequency-determining circuit, means for shifting the oscillator frequency comprising a resonant circuit including two reactances coupled by an impedance to the remainder of said frequency-determining circuit, a potential-controlled rectifier

having electrode structures respectively of opposite polarity, one of said structures comprising a pair of electrode elements differentially connected across one of said reactances and coacting with the other electrode structure to cause the reactance to be short-circuited by the rectifier when it is conducting and effectively in circuit when the rectifier is not conducting, a source of direct current marking and spacing signals for controlling said rectifier to cause it to be conducting and non-conducting alternately to produce spacing and marking carrier telegraph signals, and means to prevent the amplitude modulated direct current signals from detrimentally affecting the oscillator tuning circuit comprising a source of rectifier control potential connected to the electrical mid-point of said impedance to cause any direct current flowing through the rectifier when it is conducting to flow differentially in both sides of said resonant circuit, another source of control potential connected to said other electrode structure of the rectifier, said source of direct current marking and spacing signals being connected to said other electrode structure of the rectifier and in shunt with said source of control potential therefor.

14. In a carrier wave transmission channel, an oscillator adapted to generate a carrier current of median frequency as determined by a frequency-determining circuit, means for shifting the oscillator frequency comprising a series resonant circuit including two reactances coupled by a transformer to the remainder of said frequency-determining circuit and including a winding of said transformer, a potential-controlled rectifier having electrode structures respectively of opposite polarity, one of said structures comprising a pair of electrode elements differentially connected across one of said reactances and coacting with the other electrode structure to cause the reactance to be short-circuited by the rectifier when it is conducting and unaffected thereby when the rectifier is not conducting, a source of direct current marking and spacing signals for controlling said rectifier to cause it to be conducting and non-conducting alternately to produce spacing and marking carrier telegraph signals, and means to prevent the amplitude-modulated direct current signals from detrimentally affecting the oscillator tuning circuit comprising a source of rectifier control potential connected to the electrical mid-point of said transformer winding to cause any direct current flowing through the rectifier when it is conducting to flow differentially in both sides of said series resonant circuit, another source of control potential connected to said other electrode structure of the rectifier, said source of direct current marking and spacing signals being connected to said other electrode structure of the rectifier and in shunt with said source of control potential therefor.

15. In a signaling system, a thermionic device having an anode, a control grid and a cathode, a first grounded negative battery and means for connecting said cathode to ground through said battery, a second grounded negative battery of higher potential than said first battery, a potentiometer having one end thereof connected to ground and the other end thereof connected to said second negative battery, a connection adjustable along said potentiometer for applying a variable negative bias to said grid, and means for substantially preventing noise potentials present in both grounded batteries from affecting the grid circuit comprising a conductive connection between said cathode and a point on said potentiometer spaced from said adjustable connection on the potentiometer a distance selected to produce said negative grid bias potential applied to the tube, said conductive connection providing a short-circuit path around the major portion of the grid biasing circuit.

16. In a signaling system, a thermionic device having an anode, a control grid and a cathode, a first grounded negative battery and means for connecting said cathode to ground through said battery, a second grounded negative battery of higher potential than said first battery, a potentiometer having one end thereof connected to ground and the other end thereof connected to said second negative battery, a connection adjustable along said potentiometer for applying a variable negative grid bias to said grid, and means for minimizing the noise potentials present in both grounded batteries which would affect the grid circuit comprising a conductive connection between said cathode and a substantially equi-potential point on said potentiometer, said conductive connection providing a short-circuit path around the major portion of the grid biasing circuit.

17. In a signaling system, a telegraph leg circuit, a thermionic device having an anode, a control grid and a cathode for generating telegraph signals, said anode being connected to said leg circuit, said cathode being connected to the negative terminal of a first grounded battery thereby to supply current to the telegraph leg circuit, a second grounded negative battery of higher potential than said first battery, means for correcting signal bias in said leg circuit comprising a potentiometer having one end thereof connected to ground and the other end thereof connected to the negative terminal of said second grounded battery, a connection adjustable along said potentiometer for applying a variable negative bias to said grid, and means for substantially preventing noise potentials present in both grounded batteries from affecting the grid circuit comprising a conductive connection between said cathode and a substantially equi-potential point on said potentiometer, said conductive connection providing a short-circuit path around the major portion of the grid biasing circuit.

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