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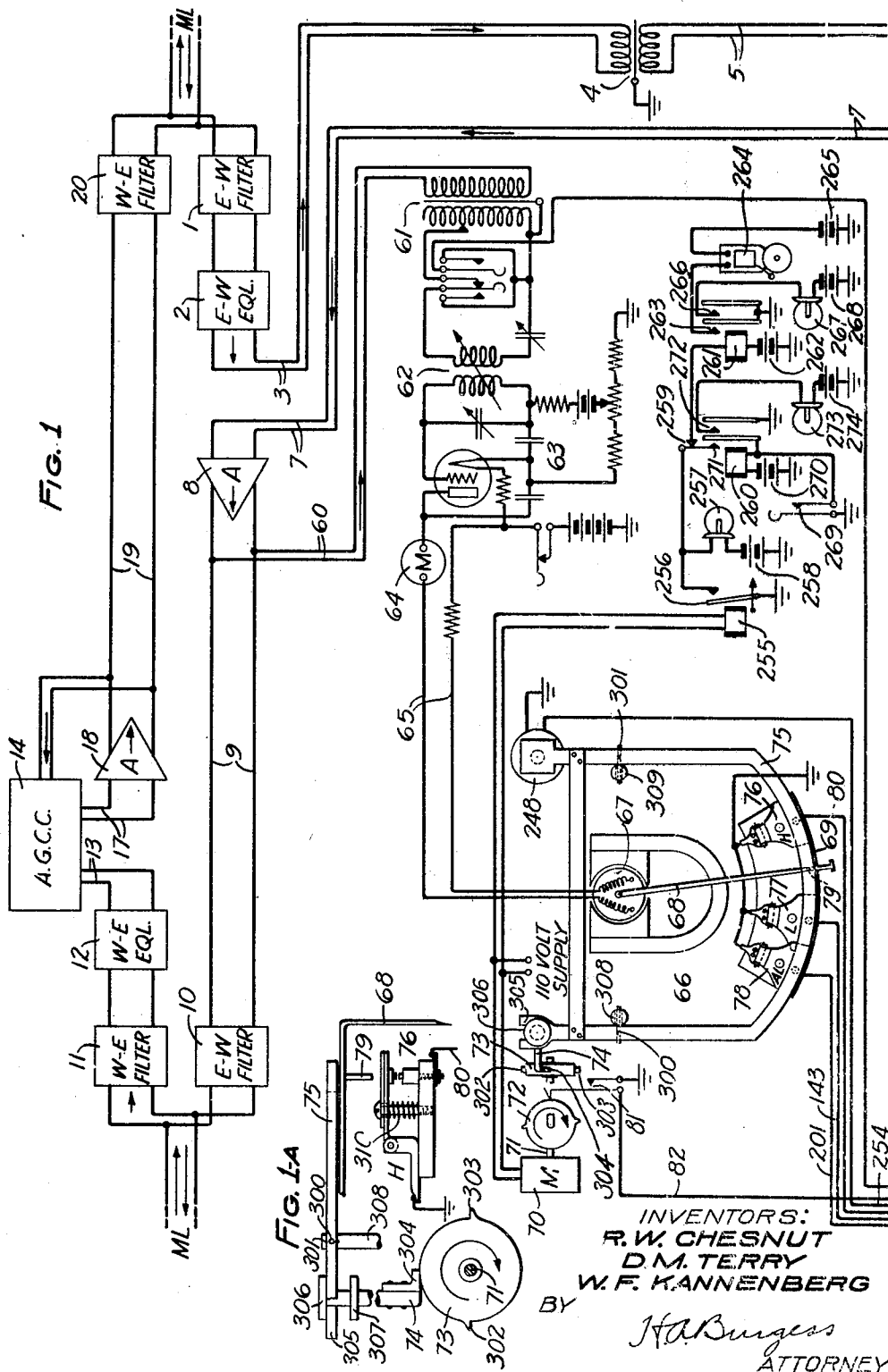
R. W. CHESNUT ET AL

1,880,800

REGULATING CIRCUITS

Filed June 26, 1929

3 Sheets-Sheet 1



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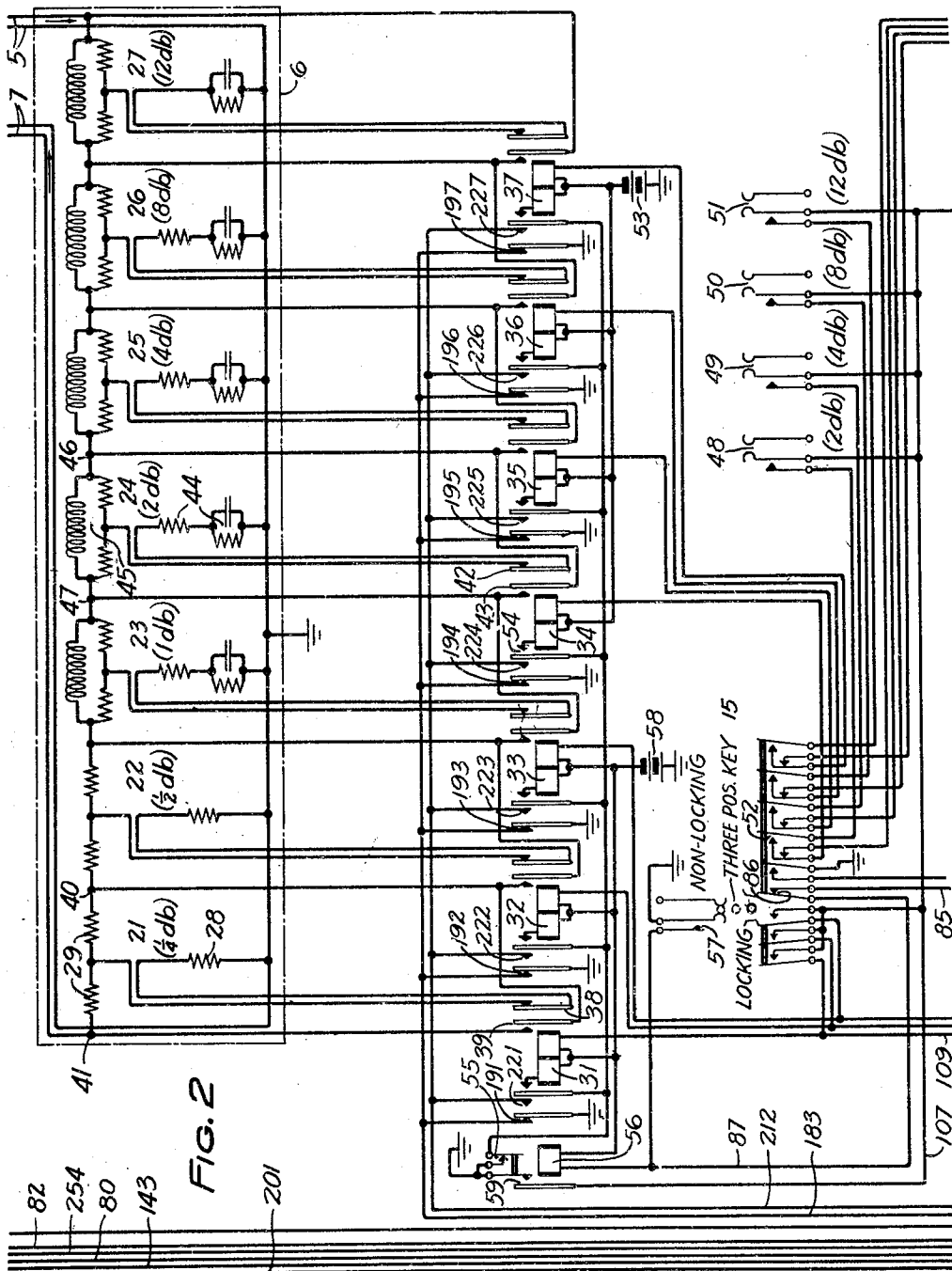
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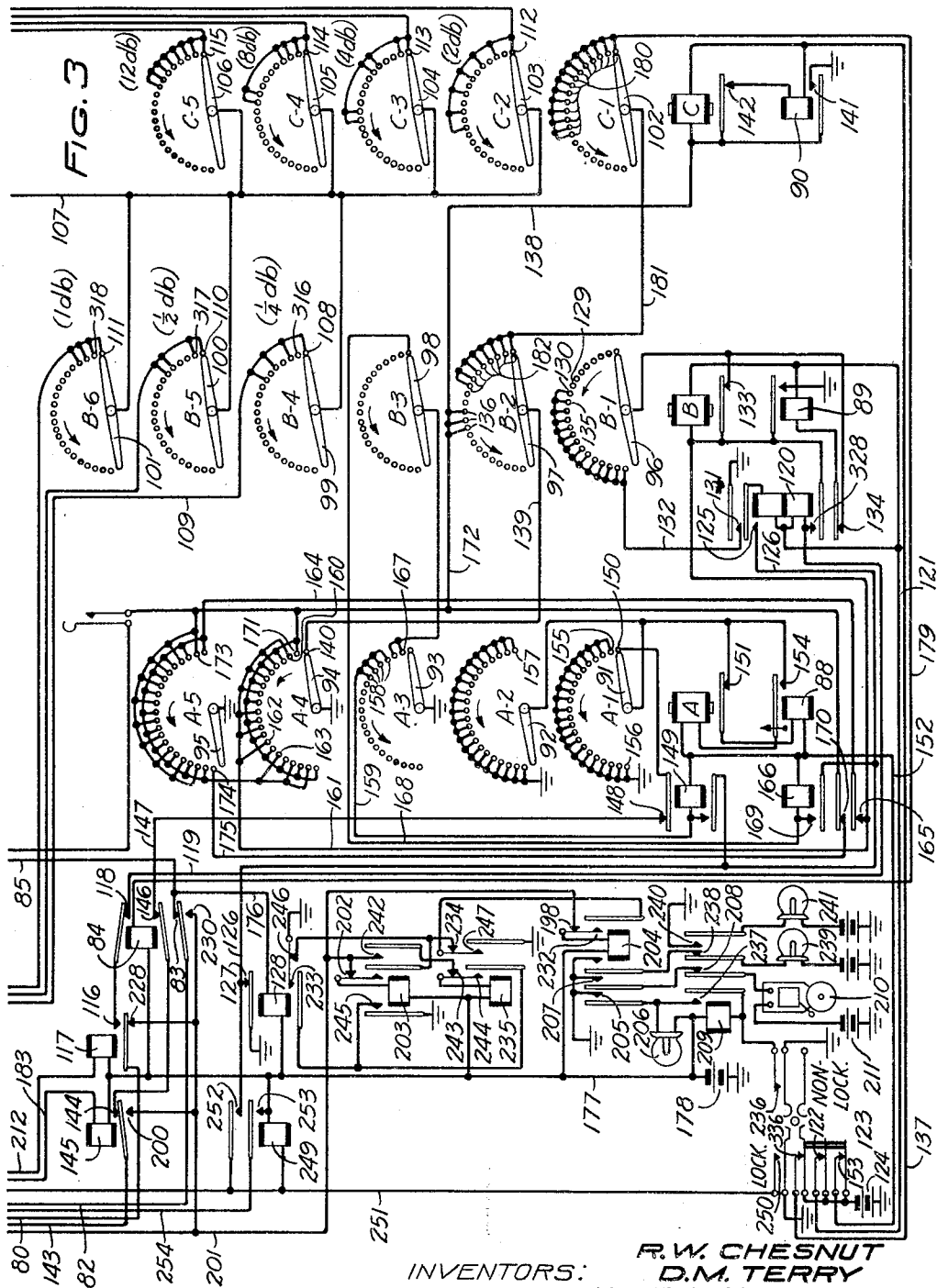
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REGULATING CIRCUITS

Application filed June 26, 1929. Serial No. 373,762.

This invention relates to electrical transmission systems and more particularly to means and methods whereby the transmission efficiency of a system may be maintained substantially constant.

Where a plurality of signals are simultaneously transmitted over a common conducting system through the agency of carrier currents of different frequencies, it is desirable that the attenuation of the carrier system as regards the several frequencies be maintained substantially constant regardless of the changes in the line conditions. Changes in the attenuation of a system of this character are due to a variety of causes but arise principally from variations in the leakage condition of the open-wire lines employed as conductors, the attenuation being much greater during wet weather than during dry weather. This source of variation in the transmission efficiency of a system is quite distinct from the usual causes of transmission variations in long cable circuits operated at ordinary telephone frequencies where the resistance variation with temperature is a controlling factor.

One of the objects of this invention is to provide means and methods whereby in a system for the transmission of signals, the transmission efficiency of the circuit may be automatically maintained substantially constant under various conditions.

Another object of this invention is to provide means and methods whereby this result may be obtained through the agency of a pilot frequency which is subjected to the changes in line conditions which affect the frequencies employed for signaling, so that elements of the circuit may be adjusted to offset the attenuation changes indicated by the pilot frequency.

Another object of the invention is to provide means and methods whereby selecting apparatus is automatically operable in response to the changes in the current from the pilot indicator to set up electrical paths in the adjusting system and to periodically transmit current through the paths so set up to effect the desired adjustment to maintain the transmis-

sion efficiency of the circuit substantially constant under various conditions.

The invention is applicable to any type of transmission system whose attenuation is subject to change, but it has especial application to multiplex carrier transmission systems and the detailed description will refer specifically to such a system.

In general the operation of the system is as follows:

The pilot currents which operate the automatic gain control circuit and the speech side band currents come in from the high frequency line and pass through directional filters, equalizers and other apparatus and then through a variable artificial line which is controlled automatically.

The automatic control circuit cuts in or out the proper number of units in the variable artificial line which attenuates the pilot current and the speech side band currents the proper amount so that when they are amplified in the receiving amplifier, the proper current level output or normal current level is maintained. From the output of the amplifier the pilot indicator current is transmitted to the input of the automatic gain control circuit.

The speech side band currents are separated at the output of the amplifier from the pilot channel current and pass through their respective band filters. The pilot current is selected by tuned circuits and rectified in a vacuum tube to give direct current. The amount of this direct current varies with the amount of the pilot current arriving so that if there are not sufficient units cut into the variable artificial line the rectified direct current will be too large. On the other hand if too many units are cut into the variable artificial line the rectifier current produced will be too small. This direct current is automatically used to cut out or in units until it adjusts itself to the desired normal level.

This adjustment is effected in the following manner. Current from a pilot indicator passes through an indicating controller. This controller consists essentially of a galvanometer through which currents from the pilot indicator are transmitted and a small

motor which causes the galvanometer pointer to be depressed at 15-second intervals. If the galvanometer indicates normal transmission level, the galvanometer pointer does not cause any of the contacts associated with the galvanometer to close when the pointer is depressed. If, however, the transmission level is other than normal, the galvanometer pointer when depressed, causes one of three contacts to close, depending on the magnitude of direct current flowing through the galvanometer. An additional pair of contacts, which will hereinafter be referred to as the "trigger" contacts, are closed by means of a cam arrangement operated by the same motor referred to above for approximately one-half second, approximately ten seconds after the pointer has been depressed. In the interval while the galvanometer pointer is not depressed it is free to move depending on the amount of current flowing in the galvanometer.

One of the three contacts which are under the control of the pointer is used for alarm purposes only and will be referred to in connection with the alarm circuit which will be described later. The other two contacts are used for the automatic regulation. If the current value is too high the "high" contact makes. If it is too low the "low" contact makes and if the current value is at the proper or normal level neither of said contacts will make.

The "high" and "low" contacts, when made, set up electrical paths through automatic selectors. The "trigger" contact later sends current through these paths to change the amount of attenuation in the variable artificial line. If the current is at the normal level so that neither of the high or low contacts makes, the automatic selectors do not change and the trigger contact sends current through the same paths as before and does not change the setting of the variable artificial line.

The various provisions of the invention for performing these functions and for carrying out the various objects will now be described in connection with the accompanying drawings to which reference will be made.

In the drawings Figs. 1 to 3, when placed above each other with Fig. 1 at the top, show in schematic form the circuit arrangements of a repeater station and associated automatic gain control system according to the invention, and Fig. 1—A shows the method employed to operate one of the contacting devices on the indicating controller by a cam arrangement which periodically causes the pointer on the indicating controller to move downward.

General signal transmission circuit

Reference will first be made to the general arrangement of the signal transmitting sys-

tem, the line ML being a multiplex carrier line extending in both directions from the repeater station shown in Fig. 1 and terminating at each of two stations. Carrier waves of distinctive frequencies may be used for effecting exclusive communication between corresponding sets in the usual manner. In addition to the signaling sets a pilot channel is also associated with the line ML in the usual manner, the pilot channel using a wave of a frequency distinct from the carrier frequencies of the signaling channels. The carrier waves and the pilot frequency waves from the east station, not shown, are transmitted over the line ML to the repeater station shown. These waves are transmitted through the east-west filter 1, the east-west equalizer 2, line section 3, transformer 4, line section 5, attenuation equalizer 6, line section 7, east-west amplifier 8, line section 9, east-west filter 10 and line ML to the west station not shown. Signal carrier waves and the pilot frequency from the west station are received over the line ML, west-east filter 11, west-east equalizer 12, line section 13, automatic gain control circuit 14, line section 17, west-east amplifier 18, line section 19, west-east filter 20 and line ML to the east station.

The complete carrier system and the repeater station may be constructed in the manner well known in the art. They may for example be constructed in accordance with the disclosure in the Bell System Technical Journal vol. VII, pp. 564-629, July 1928, entitled "Carrier Systems on Long Distance Telephone Lines" by H. A. Affel, C. S. Demarest and C. W. Green.

The filters 1, 10, 11 and 20 may be constructed in accordance with the usual practice for carrier current transmission systems. These filters may, for example, be constructed in accordance with the disclosure in U. S. Patent No. 1,227,113 to Campbell, May 22, 1917. The equalizers 2 and 12 may, for example, be constructed in accordance with U. S. Patent No. 1,603,305, to Zobel, October 19, 1926. The seven units, 21 to 27 inclusive, of the attenuation equalizer 6 may be constructed in any known manner, as for example, in accordance with the disclosure in U. S. Patent No. 1,511,013 to Affel, October 7, 1924. The amplifiers 8 and 18 may be constructed in the manner well known in the art. The automatic gain control circuit 14 may be a duplicate of the automatic gain control circuit hereinafter described in connection with the east-west signals.

The attenuation equalizer 6, as shown, comprises seven units 21 to 27 inclusive. The attenuation equalizer unit 21, for example, preferably comprises series elements 29 and shunt element 28. The other attenuation equalizer units 22 to 27 inclusive are prefer-

ably constructed similar to the equalizer unit 21.

Relays 31 to 37 inclusive are employed to operate switches, to insert the desired number of attenuation units 21 to 27 inclusive between line sections 5 and 7, to control the current amplitude transmitted to amplifier 8.

Relay 31 controls switches 38 and 39 which are associated with the attenuation unit 21. Switch 38 when closed as shown, connects the shunt element 28 of attenuation unit 21 from one side of line section 7 to the midpoint of the series elements of the attenuation unit 21. When relay 31 is operated, switch 38 opens and switch 39 closes. When switch 38 opens, the shunt element 28 is disconnected from line section 7 and when switch 39 closes, a circuit is completed from the connection 40 between the series elements of attenuation units 21 and 22, through switch 39 to the other side of line section 7 at 41, which effectively shunts out the series elements of attenuation unit 21. In this manner the attenuation unit 21, which when the relay 31 is unoperated, as shown, is connected between line sections 5 and 7, can be disconnected from between line sections 5 and 7 by the operation of relay 31.

Relay 34 controls switches 42 and 43 which are associated with the attenuation equalizer unit 24. Switch 42 when closed, as shown, connects the shunt element 44 in the circuit, in a manner similar to switch 38 on relay 32 in connection with equalizer unit 21. When relay 34 is operated, switch 42 opens and switch 43 closes. Switch 42, when opened, disconnects the shunt element 44 from the circuit and switch 43 when closed, completes a circuit from the connection 46, between attenuation units 24 and 25 through switch 43, to the connection 47, between attenuation units 23 and 24, thereby effectively short-circuiting the series element 45. Relays 32, 33, 35, 36 and 37 in a like manner control their associated attenuation units 22, 23, 25, 26 and 27.

In the system illustrated the attenuation units 21 to 27 are constructed to provide the following transmission loss: 21— $\frac{1}{4}$ db, 22— $\frac{1}{2}$ db, 23—1 db, 24—2 db, 25—4 db, 26—8 db, 27—12 db. Since any combination of these attenuation units may be inserted between line sections 5 and 7, the attenuation may be varied from zero to 27— $\frac{3}{4}$ db, in $\frac{1}{4}$ db steps.

Manual control of the attenuation equalizer

When manual control of attenuation equalizer units is desired, key 15 (Fig. 2) is moved to the neutral or "Off" position, in which neither pair of its springs is spread, and switches 48 to 51 inclusive are thereby associated with relays 34 to 37 inclusive. When switch 48 is closed and then the switch 57 on key 15 is closed by moving the switch plunger to its upper position, a circuit is completed

from ground through switch 57, relay 56 and battery 58 to ground which operates relay 56. When relay 56 operates, switch 55 is opened and switch 59 is closed. When switch 59 is closed, a circuit is completed from ground through switch 59, switch 48, switch 52 of key 15, right hand winding of relay 34 and battery 53 to ground, which operates relay 34, thereby closing switch 54 on relay 34. If, after relay 34 has operated, relay 56 is released by the opening of switch 57 a circuit will be completed from ground through battery 53, left hand winding of relay 34, switch 54 and switch 55 to ground, thereby holding relay 34 in its operated position. This is accomplished by adjusting switches 55 and 59 so that when relay 56 releases, switch 55 will close before switch 59 opens.

To release relay 34 it is only necessary to close switch 57 momentarily with switch 48 open. This will operate relay 56 as described above, thereby opening switch 55 and closing switch 59. The closing of switch 59, with switch 48 open, will not energize the right hand winding of relay 34 and when switch 55 subsequently opens, the circuit is broken through the left hand winding of relay 34 and it will release.

In a similar manner relays 35, 36 and 37 may be operated by the momentary closing of switch 57 with switches 49, 50 and 51 closed and may be released in the manner described above in connection with relay 34.

Relays 31, 32 and 33, as shown, are arranged to operate whenever switch 57 of key 15 is closed, as they are connected in a manner similar to relays 34 to 37 inclusive, except that switches similar to 48 to 51 inclusive have not been provided to break the circuits through the right hand windings of relays 31 to 33 inclusive. Relays 31 to 33 inclusive may, however, also be operated and released by providing additional switches, not shown, connected in a manner similar to switches 48 to 51 inclusive.

Since either one or all switches 48 to 51 may be opened or closed at the same time that the switch 57 is momentarily closed, any combination of the relays 31 to 37 inclusive may be operated and/or released simultaneously.

Automatic control of attenuation equalizer

When automatic control of the attenuation equalizer units is desired, key 15 is moved to the lower or locking position shown. This will prevent switches 48 to 51 inclusive from operating the relays 34 to 37 inclusive, since switch 52 on key 15 is opened and prevents completing the circuit referred to above through switch 48, and in a similar manner other switches on key 15 are opened, preventing switches 49 to 51 inclusive from completing circuits through relays 35 to 37 inclusive.

Part of the currents from the output of amplifier 8 are shunted from the line section 9 over line section 60, through transformer 61 to the tuned circuit 62. This circuit 62 is tuned to the pilot frequency and effectively suppresses the signal frequencies which are transmitted through amplifier 8. The pilot frequency currents are transmitted through the tuned circuit 62 to a rectifier 63. The direct current from rectifier 63 is transmitted through a visual indicating meter 64, and line section 65 to an indicating controller 66. Since, as stated above, the currents are transmitted through the variable attenuation equalizer 6 before reaching the amplifier 8 the amount of direct current transmitted through meter 64 to the indicating controller 66 can be controlled by varying the number of attenuation equalizer units 21 to 27 inclusive through which these currents must pass.

Description of operation of indicating controller

The indicating controller 66 comprises a galvanometer unit 67 having a pointer 68 which moves along the face 69 as the current through the galvanometer 67 changes. A motor 70 drives a shaft 71 to which are rigidly fixed cams 72 and 73. As cam 73 revolves the rod 74 is moved upward (toward the reader, in Fig. 1) for a short interval at approximately 15-second intervals, causing a bar 75 which is pivoted at points 300 and 301 to come in contact with the pointer 68 and move the pointer 68 downward (away from the reader, in Fig. 1).

Three contacting devices 76, 77 and 78 are arranged along the face 69 and beneath the pointer 68. When the pointer 68 is directly over the contacting device 76 (referred to above as the "high" contact) at the time the bar 75 depresses the pointer 68, the projection 79 on the pointer 68 closes the circuit from ground to conductor 80. If the pointer is directly over the contacting devices 77 (referred to above as the "low" contact) or 78 at the time that the pointer 68 is depressed, the circuit from ground through these contacting devices 77 or 78 will be closed in a similar manner to that shown for contacting device 76.

Fig. 1—A shows in detail the manner in which the contacting devices 76, 77 and 78 are momentarily closed by the action of cam 73. When the cam 73 is in the position shown the pointer 68 is free to move under control of the galvanometer 67, as the pointer 68 is not in contact with the bar 75. The bar 75 has a yoked portion 305, which yoke extends around the bar 75 between the head 306 and collar 307, which head and collar are rigidly fastened to the rod 74. The bar 75 is supported by the pivots 300 and 301, which pivots are rigidly fastened to supports 308 and 309.

The weight of the bar 75 to the right of the pivot 300 and 301, (Fig. 1—A), is greater than the weight of the bar on the other side of the pivots and the yoke 305 is, therefore, held against the head 306. The weight of the rod 74 is such that it prevents the bar 75 from pivoting downward on the right, (Fig. 1—A), toward the pointer 68. When either of the projecting portions 302 or 303 of the cam 73 come in contact with the L shaped member 304, which is attached to the rod 74, the rod 74 is moved upward, allowing the portion of the bar 75 to the right of pivot 300 to move downward against the pointer 68 and to move the pointer 68 downward with it. If the pointer is directly over the contacting device 76, as shown in Fig. 1—A, the projection 79 causes the contacting device 76 to close the circuit from ground to conductor 80.

When the cam 73 has moved so that neither projecting portion 302 nor 303 is in contact with the member 304 the weight of the rod 74 moves the bar 75 away from pointer 68 and the spring 310 causes the contacting device 76 to open the circuit from ground through conductor 80.

The cam 72 is arranged to close switch 81 (referred to above as the "trigger" contact) for approximately $\frac{1}{2}$ second, approximately eight seconds after the pointer 68 has been depressed and returned to a sufficient height so that the contacts 76, 77 or 78 will have opened.

The contacting devices 76 and 77 are arranged so that when the pointer 68 is directly over the space between these contacting devices the depression of the pointer will not cause the operation of either of them. The contacting device 78 is arranged, with respect to contacting device 77, so that there is no space between these contacts, in order that the contacting device 78 will be operated whenever the pointer is to the left of contacting device 77.

When the indicator 68 is between the contacting devices 76 and 77, as shown, the current level at the output of amplifier 8 is at the desired or normal level. When the current level is higher than normal the pointer 68 is moved by the galvanometer 67 over contacting device 76, and when the current level is lower than normal the pointer 68 is moved over contacting device 77 or 78. The contacting device 78 is provided for alarm purposes and will be referred to later.

In general the function of contacting devices 76 and 77 is to control the operation of automatic selectors A1 to A5 inclusive, (Fig. 3), B1 to B6 inclusive and C1 to C6 inclusive, in order that the proper circuits may be completed through relays 31 to 37 inclusive.

When the cam 72 closes switch 81, a circuit is completed from ground through switch 81, conductor 82, switch 83 on relay 84, (Fig. 3),

conductor 85, switch 86 on key 15, conductor 87, relay 56 and battery 58 to ground. This will operate relay 56 in a manner similar to its operation by switch 57 as described above and hold up any of the relays 31 to 37 inclusive which were operated by the action of the contacting devices 76 and 77.

Operation of selector switches

Selector switches A1 to A5 inclusive are operated by the magnet A, selector switches B1 to B6 by the magnet B and selector switches C1 to C5 inclusive by the magnet C.

The five contact arms 91 to 95 inclusive of the selector switch A, if desired, may be mounted on a common shaft. Likewise the six contact arms 96 to 101 inclusive of the selector switch B may be mounted on a common shaft and the five contact arms 102 to 106 inclusive of the selector switch C may be mounted on a common shaft. The step-by-step mechanisms for the contact arms are not shown in the drawings, but may be of any suitable type, and each may comprise, for example, a ratchet wheel mounted on the shaft and controlled by a stepping pawl adjacent to the magnets A, B and C, in a manner well known in the art. These contact arms will be controlled by their stepping mechanisms in such a manner as to cause them to rotate in a counter-clockwise direction.

Slow-release relay 88 is associated with selector magnet A to retard the speed of operation of the magnet A. Relay 89 is associated with selector magnet B to lock up when a pulse is received by the selector magnet B until the selector magnet B has completely operated. Relay 90 is associated with selector magnet C for the same purpose that relay 89 is associated with selector magnet B.

With the switch arms in the position shown, when the switch 81 is closed by the cam 72, which causes the operation of relay 56 as described above, the closing of switch 59 on relay 56 completes a circuit from ground through switch 59, conductor 107, switch arm 99 and contact 108 on the B4 selector switch, conductor 109, right hand winding of relay 31 and battery 58 to ground. When the relay 56 is released, due to the opening of switch 81 by the action of cam 72, relay 31 is locked up through its left hand winding in the manner described above. In a similar manner relays 32 to 37 inclusive are operated through selector switch arms 100, 101 and 103 to 106 inclusive and their associated selector switch contacts 110 to 115 inclusive. All the attenuation units 21 to 27 inclusive will then be removed from between line sections 5 and 7 after the switch 81 is closed because relays 31 to 37 are all energized.

When the B1 to B6 selectors are stepped

forward one step, in the direction indicated, by the selector magnet B the switch arm 99 of the B4 selector steps to the idle contact 316, which opens the circuit previously existing over conductor 109. The subsequent operation and release of relay 56 will cause relay 31 to release and connect the attenuation equalizer unit 21 between line sections 5 and 7. Since contacts 317 and 318 are engaged by switch arms 100 and 101, relays 32 and 33 will remain operated. In this manner, as the selector switches B1 to B6 are stepped forward and the relay 56 operated after each step, the attenuation is increased in $\frac{1}{4}$ db steps from zero to $1\frac{3}{4}$ db. This requires seven steps forward on the part of the B selector switches.

In order to increase the attenuation from $1\frac{3}{4}$ db to 2 db it is necessary to step the B1 to B6 selector switches fifteen steps forward and to step the C1 to C5 selector switches forward one step. The subsequent operation of relay 56 will remove attenuation units 21 to 23 inclusive and insert attenuation unit 24. As the selector switches B1 to B6 are again stepped forward as described above the attenuation increases in $\frac{1}{4}$ db steps from 2 db to $2\frac{3}{4}$ db. By again stepping the B1 to B6 selector switch arms to the position shown and stepping the C1 to C5 selector switch arms one step forward, the subsequent operation of relay 56 inserts the attenuation equalizer unit 25 and removes the attenuation equalizer units 21 to 24 inclusive. The further operation of the B1 to B6 selectors inclusive and C1 to C5 selectors inclusive will increase the attenuation in $\frac{1}{4}$ db steps under control of the contacting device 76 until a total of $27\frac{3}{4}$ db is reached.

In order to decrease the attenuation from $27\frac{3}{4}$ db the B1 to B6 selector switches are moved forward one step less than a complete cycle and the relay 56 is operated as described above, which will reduce the attenuation to $27\frac{1}{4}$ db. There are 22 steps in a complete cycle for the B1 to B6 selector switches and for the C1 to C5 selector switches. In a similar manner, by stepping the B1 to B6 selector switches forward one step less than the complete cycle, the attenuation is reduced in $\frac{1}{4}$ db steps until 26 db is reached. At this point it is necessary to move the C1 to C5 selector switches forward 21 steps or one step less than a complete cycle and to move the B1 to B6 selector switches forward 7 steps, in order to reduce the attenuation to $25\frac{3}{4}$ db. In this manner the attenuation can be reduced in $\frac{1}{4}$ db steps until zero attenuation is reached.

Operation of the automatic circuit

When the pointer 68 of the indicating controller 66 is between the contacts 76 and 77 as shown, no one of the contacts 76, 77 or 78 will be operated by the action of cam 73, and each time the switch 81 (referred to above as the

trigger contact) is closed under control of cam 72, current is transmitted through the right hand windings of the relays 31 to 37 inclusive which are connected to battery through the selector switch arms B1 to B6 inclusive and C2 to C5 inclusive as described above.

If some one or more of the attenuation units 21 to 27 inclusive are inserted between line sections 5 and 7 when the line conditions change and the pointer 68 is moved over contact 76, the closing of contact 76 by the action of cam 73 completes a circuit from ground through contact 76, conductor 80, switch 116 of relay 117, switch 118 of relay 84, conductor 119, lower winding of relay 120, conductor 121, switch 122 on key 123 and battery 124 to ground, thereby operating relay 120. Switch 116 on relay 117 has been shown in an opened position. It will, however, be closed whenever any of the attenuation units 21 to 27 inclusive are cut out between line sections 5 and 7. The function of switch 116 and relay 117 will be more fully explained below in connection with the alarm circuits.

When relay 120 operates, switch 125 closes, completing a circuit from ground through battery 124, switch 123, conductor 121, upper winding on relay 120, switch 125 on relay 120, conductor 126 and switch 127 on relay 128 to ground, thereby holding the relay 120 in an operated position. Relay 120, when operated, also completes a circuit from ground through contact 76 on the indicating recorder 66, conductor 80, switch 116, switch 118, conductor 119, switch 328, selector magnet B, conductor 121, switch 122 and battery 124 to ground.

When the contact 76 is broken by the action of cam 73 the selector switch arms 96 to 101 inclusive on the B selector are stepped forward one step. The first six steps which the B selector takes are accomplished in this same manner under control of galvanometer 66. When the selector switch arm 96 of the B1 selector is stepped from contact 129 to contact 130 a circuit is completed from ground through switch 131 on relay 120, conductor 132, selector switch contact 130, selector switch arm 96, switch 133 on selector magnet B, selector magnet B, conductor 121, switch 122 and battery 124 to ground, thereby operating the selector switch magnet B which interrupts its own circuit at contact 133 and moves selector switch arms 96 to 101 inclusive over the remaining selector switch contacts. The B selector switches will thus be stepped forward, to the position shown, which opens the circuit from selector switch arm 96 to conductor 132.

Relay 120 by being held in the operated position in the manner described above enables the B selector switches to move more than one step forward when switch 76 on the indicating recorder 66 is closed even though

the switch 76 opens before the B selector switches have stepped forward to the positions shown. Relay 120 also opens switch 134 which disconnects relay 89 from the circuit. Relay 89 has no function at this time. Its purpose will be described later in connection with the operation of the A selectors which control the B selectors to increase the gain.

When the selector switch arm 97 on the B2 selector switch makes contact with selector switch contacts 136 a circuit is completed from ground through battery 124, switch 336 of key 123, conductor 137, selector switch magnet C, conductor 138, selector switch contacts 136 on the B2 selector switch, selector switch arm 97, conductor 139, selector switch contact 140 on the A4 selector switch and selector switch arm 94 to ground, which operates selector switch magnet C and relay 90 and steps selector switch arms 102 to 106 inclusive one step forward. When relay 90 operates, it closes switch 141 maintaining the ground connection to the selector switch magnet C until selector switch magnet C has completely operated and opened the switch 142, even though the selector switch arm 97 has been stepped beyond selector switch contacts 136 before selector switch magnet C has operated.

When the switch 81 is closed by the action of cam 72, a circuit is completed from ground through switch 81, conductor 82, switch 83, conductor 176, relay 128, conductor 177 and battery 178 to ground, thereby operating relay 128 and opening switch 127. When switch 127 opens the locking circuit through relay 120 is broken, allowing relay 120 to return to its normal position.

In a similar manner the total attenuation between line sections 5 and 7 can be increased in $\frac{1}{4}$ db steps as long as pointer 68 remains over the contact 76.

When line conditions change and the indicating pointer 68 moves over the contact 77, indicating that the attenuation of the attenuation equalizer is too large, the system operates to decrease the attenuation in $\frac{1}{4}$ db steps by stepping the selector switch arms forward one step less than a complete cycle as described above. This is accomplished by supplying the proper number of stepping impulses to the B and C selectors by means of selector switches A1 to A5 inclusive.

When the cam 73 causes switch 77 to close a circuit is completed from ground through switch 77, conductor 143, switch 144 on relay 145, switch 146 on relay 84, conductor 147, switch 148 on relay 149, selector switch contact 150 on the A1 selector switch, selector switch arm 91 on selector switch A1, switch 151 on selector switch magnet A, relay 88, conductor 152, switch 153 on key 123 and battery 124 to ground, which operates relay 88, it being noted that relays 145 and 84 are now ener-

gized under control of switches 191 to 197 inclusive (Fig. 2) and the A, B and C selectors (Fig. 3) respectively. When relay 88 operates, switch 154 closes, extending the previously traced lead from ground on contact 77 to selector switch magnet A, conductor 152, switch 153 and battery 124 to ground thereby operating the selector switch magnet A. When the selector switch magnet A operates, switch 151 opens the above mentioned circuit through relay 88 and relay 88 releases. When relay 88 releases it opens switch 154 on relay 88, allowing selector switch magnet A to release and rotate selector switch arms 91 to 95 inclusive one step forward in the direction indicated.

When the selector switch arm 91 of the A1 selector switch is stepped forward it makes contact with selector switch contact 155, completing a circuit from ground through battery 124, switch 153 on key 123, conductor 152, relay 88, switch 151, selector switch arm 91 and selector switch contact 155 to ground, thereby operating relay 88. The operation of relay 88 operates selector switches A1 to A5 inclusive an additional step forward as described above. Since all the selector switch contacts on selector switch A1, except contact 150, are connected directly to ground the above operation is repeated until selector switch arm 91 has stepped forward from the last selector switch contact 156. Selector switch arm 92 of the A2 selector switch makes contact with selector switch 157 when selector switch arm 91 is stepped forward from selector switch contact 156. The operation of relay 88 and selector switch magnet B is repeated by the ground connection through the selector switch arm 92 until the selector switch arms 91 to 95 inclusive have been stepped forward a complete cycle of 44 steps and returned to the position shown.

As the relay 88 must operate between every step of the A selector switch, it slows down the operation of the A selector switch, so that the current impulses received by the B and C selector switches from the A4 and A5 selector switches will not be transmitted too rapidly.

When the selector switch arm 93 of the A3 selector switch makes contact with selector switch contacts 158, a circuit is completed from ground through selector switch arm 93, selector switch contacts 158, conductor 159, relay 149, conductor 152, switch 153 and battery 124 to ground, which operates relay 149. The operation of relay 149 opens the switch 148, which opens the circuit from ground through the contacting device 77 on the indicating controller 66 and relay 88, thereby preventing the further rotation of selector switch arms 91 to 95 inclusive if the selector switch arm 91 makes contact with selector switch contact 150, before switch 77 has opened un-

der the control of cam 73. After switch 77 opens the closing of switch 81 operates relay 128, thereby opening the circuit through switch 127 and relay 149, relay 149 releases and the system is in condition for the next cycle.

The function of selector switches A4 and A5 is to complete certain circuits so that the B and C selectors will receive the proper current impulses when the pointer 68 on the indicating controller 66 causes switch 77 to close.

When selector switch arm 94 on the A4 selector makes contact with selector switch contact 160, a circuit is completed from ground through selector switch arm 94, selector switch contact 160, conductor 161, selector magnet B, conductor 121, switch 122 and battery 124 to ground, which operates the relay 89 and the selector switch magnet B in the manner described above, for relay 90 and selector magnet C, it being noted that relay 120 is deenergized at this time, allowing circuit of relay 89 to be made through back contact 134.

The selector switch arms 96 to 101 inclusive on the B selector are thus stepped forward, when the selector switch arm 94 of the A4 selector switch contacts with every other selector switch contact for seven steps at the conclusion of which the selector switch arm 94 is in contact with contact 162. After the selector switch arm 94 has contacted with selector switch contact 163, selector switch arms 96 to 101 inclusive of the B selector are stepped forward for fourteen additional steps in a similar manner, except that the circuits from battery 124, through relay 89 and selector switch magnet B are completed through selector switch contacts 163 and each alternate succeeding contact on the A4 selector switch and through selector switch arm 95 and each alternate contact of selector switch A5, conductor 164, and switch 165 on relay 166.

When the B selector switch arms 96 to 101 inclusive are on the first step, in the position shown, and the switch 77 closed by the action of cam 73, it is necessary that the B selector switch arms 96 to 101 inclusive be stepped forward seven steps as described in the preceding paragraph instead of the usual twenty-one, but it is also necessary to step the C selector switch arms 102 to 106 inclusive forward twenty-one steps (which is one step less than a complete cycle) causing the B selector to insert 1 db, $\frac{1}{2}$ db. and $\frac{1}{4}$ db attenuation equalizer units and the C selector to remove the 2 db unit.

This is accomplished as follows: When the A3 selector switch arm 93 moves forward one step from the position shown, switch arm 93 makes contact with selector switch contact 167, completing a circuit from ground through selector switch arm 93, contact 167, selector switch arm 98 of the B3 selector, conductor 168, relay 166, conductor 152, switch

153 and battery 124 to ground thereby operating relay 166. When relay 166 operates, switch 169 closes a circuit from ground through switch 127 on relay 128, conductor 126, switch 169 on relay 166, relay 166, conductor 152, switch 153 and battery 124 to ground, thereby holding relay 166 in its operated position.

As the selector switch 94 of the A4 selector makes contact with selector switch contact 171, and each alternate contact on the A4 selector switch, a circuit is completed from ground through selector switch arm 94, conductor 172, conductor 138 through the selector switch magnet C and relay 90, which operates the selector switch magnet C and relay 90 as described above, and steps the selector switch arms 102 to 106 inclusive of the C selector eleven steps forward (there being eleven circuit closures by arm 94). Two additional steps of the A selector brings selector switch arm 95 in contact with selector switch contact 173, completing a circuit from ground through selector switch arm 95 and the selector switch magnet C and relay 90, which steps selector switch arms 102 to 106 inclusive of the C selector forward in the manner described above. This is repeated on each alternate contact of selector switch A5 for ten steps. The C selector switch arms 102 to 106 inclusive have then been stepped forward twenty-one steps, or one less than a complete cycle. When selector switch arm 95 of the A5 selector switch contacts with selector switch contact 174, as relay 166 has already operated to open switch 170 the selector switch arm 95 is prevented from completing the circuit from ground through selector switch arm 95, conductor 175, switch 170, conductor 172, conductor 138 and selector switch magnet C and relay 90, which circuit if completed would step the selector switch arms 102 to 106 inclusive of the C selector forward an additional step.

The operation of relay 166 also opens switch 165, thereby opening the circuit from ground through selector switch arms 94 and 95, selector switch contacts on the A4 and A5 selector switches, conductor 164, switch 165, selector switch magnet B and relay 89 to battery 124, thereby preventing the selector switch arms 94 and 95 from operating the selector switch magnet B and relay 89, after selector switch arm 94 has been stepped past selector switch contact 162. (There having already been seven circuit closures through the switch arm 94 and the selector switch magnet B as described above.)

The subsequent closing of switch 81 (the trigger contact) by the action of cam 72 completes a circuit from ground through switch 81, conductor 82, switch 83, conductor 176, relay 128, conductor 177 and battery 178 to ground thereby operating relay 128 and opening the switch 127. When switch 127 opens,

the holding circuit through relay 166 is broken, which allows relay 166 to release and return to its normal position.

In a similar manner the total attenuation between line sections 5 and 7 can be decreased in $\frac{1}{4}$ db steps as long as pointer 68 remains over contact 77.

Alarm relays and circuits

When all the attenuation units 21 to 27 inclusive have been removed from between line sections 5 and 7 by the operation of relays 31 to 37 inclusive, the circuit from ground through battery 178, conductor 177, relay 145, conductor 183 and switches 191 to 197 inclusive on relays 31 to 37 inclusive to ground is broken, by the opening of switches 191 to 197 inclusive. This causes relay 145 to release, which opens switch 144, preventing the operation of the selector switches when contact 77 is closed, and closes switch 200. The subsequent closing of switch 77, by the action of cam 73, completes a circuit from ground through switch 77, conductor 143, switch 200, conductor 201, switch 202 on relay 203, relay 203, conductor 177 and battery 178 to ground, and also completes another circuit from ground through switch 77, conductor 143, switch 200, conductor 201, switch 198 on relay 204, relay 204, conductor 177, battery 178 to ground, thereby operating relays 203 and 204. When relay 204 operates, switch 198 is opened, and switch 232 is closed, thereby completing a circuit from ground through switch 246 on relay 128, switch 234 on relay 235, switch 232 on relay 204, relay 204, conductor 177 and battery 178 to ground, thereby locking up relay 204 in its operated position.

The operation of relay 204 closes switch 205, completing a circuit from ground through switch 205, lamp 206 and battery 178 to ground, thereby lighting lamp 206, and also completes a circuit from ground through switch 207, switch 208 on relay 209, bell 210 and battery 211 to ground, thereby ringing bell 210.

When desired, the alarm bell 210 may be stopped by closing switch 236 on key 123, which completes a circuit from ground through switch 236, relay 209 and battery 178 to ground, thereby operating relay 209. When relay 209 operates, it is held in that position by the completed circuit from ground through battery 178, relay 209, switch 237 on relay 209 and switch 205 on relay 204 to ground. Relay 209 will remain in its operated position until switch 205 is broken by the release of relay 204.

The operation of relay 209 also opens switch 238, extinguishing lamp 239 and closes switch 240, lighting lamp 241, thereby indicating that the relay 209 is in an operated position.

When all the attenuation equalizer units

21 to 27 inclusive have been connected between the line sections 5 and 7, due to relays 31 to 37 inclusive being released as shown, the circuit from ground through battery 178, conductor 177, relay 117, conductor 212 and switches 221 to 227 inclusive to ground is broken, by the opening of switches 221 to 227 inclusive, which causes relay 117 to release as shown. If subsequently the indicator pointer 68 is directly over contact 76 and causes the closing of contact 76 by the action of cam 73 a circuit is completed from ground through switch 76, conductor 80, switch 228, conductor 201 and relays 203 and 204, causing these relays 203 and 204 to operate as described above. Due to the opening of switch 116 on relay 117, the operation of the selector switches, as described above, under control of the "high" contact 76 is prevented.

Relay 84 is energized under control of the A, B and C selectors, as will be described presently and if the A, B or C selectors fail to function properly, relay 84 will be released, since the circuit through switch arms 102 on the C1 selector, 97 on the B2 selector, and 94 on the A4 selector will be broken. When relay 84 is released the switches 83, 146 and 118 are opened, preventing the operation of the selector circuits when the "high" or "low" contacts 76 and 77 are closed and thereby preventing the operation of relays 31 to 37 inclusive when the switch 81 ("trigger contact") is closed. Switch 230 on relay 84 closes when relay 84 releases. The subsequent operation of switch 81 by cam 72 completes a circuit from ground through switch 81, conductor 82, switch 230, conductor 201 and relays 203 and 204, operating these relays and the alarms as described above.

If an open circuit occurs in the line ML or in the transmission path from line ML through filter 1, equalizer 2, line section 3, transformer 4, line section 5, attenuator 6, line section 7, amplifier 8, or in the line section 60 and the associated apparatus between line section 60 and indicating recorder 66, the indicating pointer 68 will return to the zero position over contacting device 78. When switch 78 is closed by the action of cam 73, a circuit will be completed from ground through switch 78, conductor 201 and relays 203 and 204, thereby operating relays 203 and 204, which causes lamp 206 to light and the alarm bell 210 to ring as described above.

Since cam 73 causes the closing of one of switches 76, 77 or 78 every 15 seconds, except when the pointer 68 is between switches 76 and 77, and since it is also desirable to have the alarm circuits automatically restore to normal if the indicating pointer moves over contacting devices 76 or 77, it is necessary to keep the alarm circuits from restoring, provided switch 78 is closed once in every 15-second cycle. Since as stated above, relay

204 is held operated by the circuit through switch 232, this circuit must be opened to release relay 204. Relays 128, 203 and 235 are utilized to cause relay 204 to remain in its operated position as long as switches 78 and 81 are alternately closed by the action of cams 73 and 72, respectively.

When switch 78 is closed, relay 203 operates as described above. The operation of relay 203 closes switch 242, completing a circuit from ground through switch 78, conductor 201, switch 242, switch 243 on relay 235, relay 235, conductor 177 and battery 178 to ground, thereby operating relay 235. When relay 235 operates, switch 243 opens and switch 244 closes. When switch 244 closes, a circuit is completed from ground through battery 178, conductor 177, relay 235, switch 244 on relay 235, and switch 245 on relay 203 to ground, which holds relay 235 in its operated position. When switch 81 subsequently closes, relay 128 is operated as above described. Relay 128, when operated, closes switch 233, holding relay 235 operated and also opens switch 246, which breaks a circuit through relay 203, causing relay 203 to release. Relay 203, when released, opens switch 245, which breaks the circuit from ground through switch 245 to relay 235. In this manner relay 235 remains operated until relay 128 is released in the manner described above.

If during the subsequent cycles of the depression of the indicating pointer 68 by the action of cam 73 and the closing of switch 81 by the action of cam 72, the relay 203 is and remains operated during the interval in which relay 128 operates and releases under control of switch 81, the switch 247 on relay 235 will complete a circuit from ground through switch 247, switch 232 on relay 204, relay 204, conductor 177 and battery 178 to ground thereby holding the relay 204 in its operated position. Since relay 235 will release only after relay 128 has released, it will therefore maintain relay 204 in its operated position until relay 128 has released. However, when relay 128 releases, relay 204 is still maintained in its operated position by the circuit referred to above from ground, switch 246 on relay 128; etc., through relay 204.

If, however, when relay 128 subsequently operates, and the operation of relay 128 is not followed by the closing of switch 78, the relay 235, being in its unoperated position, the circuit referred to above which holds relay 204 operated will be opened and relay 204 will release, restoring relay 209 to its unoperated position.

In a similar manner the alarm circuits are held in an operated position when all the attenuation equalizer units have been inserted between line sections 5 and 7, as long as the high contact 76 and the trigger contact

81 are alternately closed by the action of cams 73 and 72 respectively, by means of the switches described above which are operated by relay 117. The alarm circuits will release on the failure of switch 76 to close after switch 81 has closed. In a similar manner relay 145 controls the holding of the alarm circuits in an operated position when all attenuation equalizer units have been removed from between line sections 5 and 7 and the low contact 77 and trigger contact 81 periodically close. The alarm circuits are restored to normal on the failure of switch 77 to close after switch 81 has closed.

In order that an alarm will be given when the A, B and C selectors fail to function properly, switches have been provided on relay 84 to prevent the above described operation of the selectors when the "high" or "low" contacts 76 and 77 are closed and to cause the "trigger" contact 81 to close a circuit through the alarm relays. The function of relay 84 is to release when the A selector switch arms 91 to 95 inclusive are in any position other than the normal positions shown, when the B selector switch arms 96 to 101 inclusive are in any other position than in connection with one of the first eight selector switch contacts and when the C selector switch arms 102 to 106 inclusive are in any position except in contact with the first fourteen selector switch contacts. When relay 84 is released, switch 81 is connected in the circuit with the alarm relays and is disconnected from relays 128 and 56, which results in the opening of the circuits described above from the high and low contacts 76 and 77 to the selector switch circuits. The circuit through relay 84 is from ground through battery 178, conductor 177, relay 84, conductor 179, any one of the fourteen selector switch contacts 180 of the C1 selector switch, selector switch arm 102, conductor 181, any one of the eight selector switch contacts 182 on the B2 selector switch, selector switch arm 97, conductor 139, selector switch contact 140 on the A4 selector switch and selector switch arm 94 to ground.

In this manner the transmission of current due to the closing of switch 81 is transferred from its normal path through relays 128 and 56 to relays 203, 204 and 235. In this case the relays 203 and 235 do not release periodically as described above for the other alarm circuits. As soon as the selector switches return to their proper positions, so that relay 84 is again operated, the current transmitted by the closing of switch 81 will operate relay 128 as described above and release relays 103 and 235, and the subsequent closing of switch 81 will release the alarm circuits in the manner referred to above.

In order that the indicating pointer 68 shall not be held clamped in any position if the motor 70 should stop and also to prevent the pointer 68 from closing contacts 76, 77

or 78 during manual operation of the system, a magnet 248 and an associated relay 249 (Fig. 3) are provided to prevent the bar 75 from coming in contact with the pointer 68 by the action of cam 73. Relay 248 is operated by closing switch 250 of key 123, which completes a circuit from ground through switch 250, conductor 251, relay 249, conductor 177 and battery 178 to ground. Relay 248 is held in its operated position by a circuit from ground through switch 127 on relay 128, switch 252 on relay 249, relay 249, conductor 177 and battery 178 to ground. When relay 249 operates, switch 253 closes, completing a circuit from ground through battery 178, conductor 177, switch 253, conductor 254, and magnet 248 to ground. The relay 249 and the magnet 248 are, therefore, held in an operated position until after relay 128 has operated in response to current transmitted through relay 128 by the closing of switch 81 on the indicating controller.

An additional alarm circuit is employed to indicate the failure of the voltage source to which the motor 70 is connected. Relay 255 (Fig. 1) is normally in an operated position. Upon failure of the voltage source relay 255 releases, closing switch 256. When switch 256 closes, a circuit is completed from ground through switch 256, lamp 257 and battery 258 to ground, thereby lighting lamp 257. Another circuit is completed from ground through switch 256, switch 259 on relay 260, relay 261 and battery 262 to ground, thereby operating relay 261. When relay 261 operates switch 263 closes, completing a circuit from ground through switch 263, bell 264 and battery 265 to ground, thereby ringing bell 264. Switch 266 is also closed by the operation of relay 261, completing a circuit from ground through switch 266, lamp 267 and battery 268 to ground, thereby lighting lamp 267. When desirable, the ringing of bell 264 can be stopped by closing switch 269, thereby completing a circuit through relay 260 and battery 270 to ground. Switch 259 is opened and switches 271 and 272 are closed by the operation of relay 260. When switch 259 opens relay 261 releases, opening the circuit through the bell 264 and the lamp 267. When switch 271 closes, a circuit is completed from ground through battery 270, relay 260, switch 271 to ground, thereby holding relay 260 in its operated position. When switch 272 closes, a circuit is completed from ground through switch 272, lamp 273, battery 274 to ground, thereby lighting lamp 273. The alarm circuit is restored to its normal position by the operation of relay 255 which opens switch 256.

Although this invention has been described in connection with certain specific embodiments it is intended to be limited only by the scope of the appended claims.

What is claimed is:

1. The method of regulating a characteristic of an electrical circuit which consists in setting up electrical paths in accordance with the condition of said characteristic and periodically and only at times intermediate and differing by an appreciable interval from, the times of the successive setting up operations transmitting currents through said paths to effect the desired adjustment of said electrical circuit.

2. The method of regulating a characteristic of an electrical circuit, comprising setting up electrical control paths in accordance with the condition of said characteristic, periodically changing said paths when said condition calls for a change in regulation, and effecting the change in regulation by sending current impulses through said control paths that have been set up, only at times intermediate and differing from the times of the successive setting up operations.

3. In combination, means to be regulated, regulating means, means for producing an indication of the characteristic of said means to be regulated, means for setting up electrical paths in accordance with the indication produced, and means for periodically and only at times intermediate and differing by an appreciable interval from, the times of the successive setting up operations transmitting currents through said paths to effect the desired adjustment of said regulating means.

4. In a signaling circuit, transmission regulating means therefor comprising a response element, means for varying the transmission level, and means for controlling said means for varying the transmission level by said response element, said controlling means setting up electrical paths and periodically and only at times intermediate and differing by an appreciable interval from, the times of the successive setting up operations transmitting currents through said paths to effect the desired adjustment of said regulating elements.

5. In a signaling circuit, transmission regulating means therefor comprising a response element, means for varying the transmission level, and means for controlling said varying means comprising means for selectively setting up electrical paths under control of said response element, and means operative in the intervals intermediate the successive setting up operations to effect the desired adjustment of said regulating elements.

6. In a signaling circuit, transmission regulating means therefor, said means comprising a response element, means for varying the transmission level, and means for controlling said means for varying the transmission level, said controlling means comprising means automatically operable in response to

said response element to select electrical paths and means to transmit currents periodically and within the intervals intermediate the successive setting up operations through said paths to effect the desired adjustment of said means for varying the transmission level.

7. In a transmission system, transmission regulating means comprising an element responsive to different transmission conditions in said system, means for periodically associating said element with the system to permit said element to give a response corresponding to the transmission condition of said system, means for adjusting the transmission level of the system, electrical response elements for controlling said last mentioned means, means placing said last mentioned response elements under the control of said first mentioned response element when the latter is associated with said transmission system, and means for causing said electrical response elements to exercise control of said means for adjusting the transmission level intermediate the times of association of said first mentioned response element with said transmission system.

8. In a regulator system, regulator means adjustable in steps, a step-by-step control system for effecting the adjustment of said regulator means, including means for automatically stepping the control system to effect an adjustment in the regulator means, a measuring instrument responsive to electrical variations in a system to be regulated, means under the joint control of said measuring instrument and said control system for adjusting said regulator means from any adjustment to any new adjustment within its range, means automatically operable for rendering said adjusting means inoperative when either limit of said adjustment range is reached, and for giving an alarm, and means automatically operable for stopping said alarm and again rendering said adjusting means operative when said regulator means requires a new adjustment within its range.

9. In a regulator system, regulator means adjustable in steps, a measuring instrument responsive to electrical variations in a system to be regulated, impulse sending means under control of said instrument, stepping means controlled by said impulses for effecting an adjustment in the regulator means, dependent in extent upon the number of impulses sent under control of the measuring instrument, and means automatically operable under control of said stepping means to prevent impulses from being transmitted to said stepping means when said stepping means fails to function properly.

10. In a regulator system, regulator means adjustable in steps, a measuring instrument responsive to electrical variations in a system to be regulated, one-way rotary switches

adapted to change the adjustment of said regulator means in one direction only, other one-way rotary switches adapted to control the number of steps of said first mentioned one-way rotary switches to change the adjustment of said regulator means in the other direction, and impulse sending means under control of said instrument adapted to control said other rotary switches.

11. In a regulator system, regulator means adjustable in steps, a measuring instrument responsive to electrical variations in a system to be regulated, one-way rotary switches adapted to change the adjustment of said regulator means in one direction only, other one-way rotary switches adapted to control the number of steps of said first mentioned one-way rotary switches to change the adjustment of said regulator means in the other direction, impulse sending means under control of said instrument adapted to set up electrical paths through said rotary switches and other impulse sending means under control of said instrument adapted to transmit electrical impulses through said electrical paths.

12. In a regulator system, regulator means adjustable in steps, a measuring instrument responsive to electrical variations in a system to be regulated, one-way rotary switches adapted to change the adjustment of said regulator means in one direction only, other one-way rotary switches adapted to control the number of steps of said first mentioned one-way rotary switches to change the adjustment of said regulator means in the other direction, impulse sending means under control of said instrument adapted to set up electrical paths through said rotary switches and to transmit electrical impulses through said electrical paths, and means to prevent said impulse sending means from setting up new paths from said rotary switches and from sending electrical impulses through said paths when said rotary switches fail to function properly.

13. In a regulator system, regulator means adjustable in steps, a measuring instrument responsive to electrical variations in a system to be regulated, one-way rotary switches adapted to change the adjustment of said regulator means in one direction only, other one-way rotary switches adapted to control the number of steps of said first mentioned one-way rotary switches to change the adjustment of said regulator means in the other direction, impulse sending means under control of said instrument adapted to set up electrical paths through said rotary switches, and means to cause said impulse sending means to operate alarm means when said rotary switches fail to function properly.

14. In a regulator system, regulator means adjustable in steps, a measuring instrument responsive to electrical variations in a system to be regulated, one-way rotary switches

adapted to change the adjustment of said regulator means in one direction only, other one-way rotary switches adapted to control the number of steps of said first mentioned one-way rotary switches to change the adjustment of said regulator means in the other direction, alarm means including impulse sending means under control of said instrument adapted to put an alarm circuit in an operative condition and to maintain said alarm circuit in said operative condition during the time in which said impulse sending means periodically operates and to put said alarm circuit in a non-operative condition on the failure of said impulse sending means to periodically operate.

15. In a signaling system, transmission regulating means therefor comprising a response element, means for varying the transmission level, means for controlling said means for varying the transmission level by said response element, comprising stepping mechanism for setting up electrical paths and periodically transmitting currents through said paths to effect the desired adjustment of said regulating elements, and means automatically operable under control of said stepping mechanism for preventing said stepping mechanism from setting up electrical paths and periodically transmitting currents through said paths to effect a new adjustment of said regulating element when said stepping mechanism fails to function properly.

16. In a regulator system, regulator means adjustable in steps, a measuring instrument responsive to electrical variations in a system to be regulated, one-way step-by-step rotary switches adapted to change the adjustment of said regulator means in either direction, impulse sending means under control of said instrument adapted to rotate said one-way rotary switches to change the adjustment of said regulator means in one direction, other one-way rotary switches adapted to set up electrical paths under control of a single impulse from said measuring instrument to cause said first mentioned one-way step-by-step rotary switch to automatically rotate through a definite number of steps to change the adjustment of said regulator means in the other direction.

17. In a regulating system arranged for both automatic and manual operation, means to be regulated, a plurality of regulating elements, a deflecting member responsive to change of conditions affecting the characteristics of said means to be regulated, means for effecting automatic operation of said regulating system including a pivoted member adapted to engage said deflecting member, a periodically operating member adapted to actuate said deflecting member through said pivoted member, a plurality of stationary contacting devices cooperating with said de-

deflecting member, connections from said stationary contacts for controlling the number of said regulating elements associated with said means to be regulated, and means actuated when said system is placed under manual control for preventing said periodically operating member from actuating said deflecting member through said pivoted member while maintaining said deflecting member responsive to change of conditions affecting the characteristics of said means to be regulated, said last mentioned means comprising an electromagnet associated with said pivoted member.

18. In a regulating system, means to be regulated, regulating means, means for producing an indication of the characteristic of said means to be regulated, means for automatically setting up electrical paths in accordance with the indication produced, means for transmitting currents through said paths to effect the desired adjustment of said regulating means, means for manually setting up electrical paths to effect an adjustment of said regulating means and for rendering inoperative said means for automatically setting up electrical paths while maintaining the others of said means in an operative condition.

In witness whereof, we hereunto subscribe our names this 24th day of June, 1929.

ROY W. CHESNUT.

DONALD M. TERRY.

WALTER F. KANNENBERG.