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SIGNAL TRANSMISSION LINE

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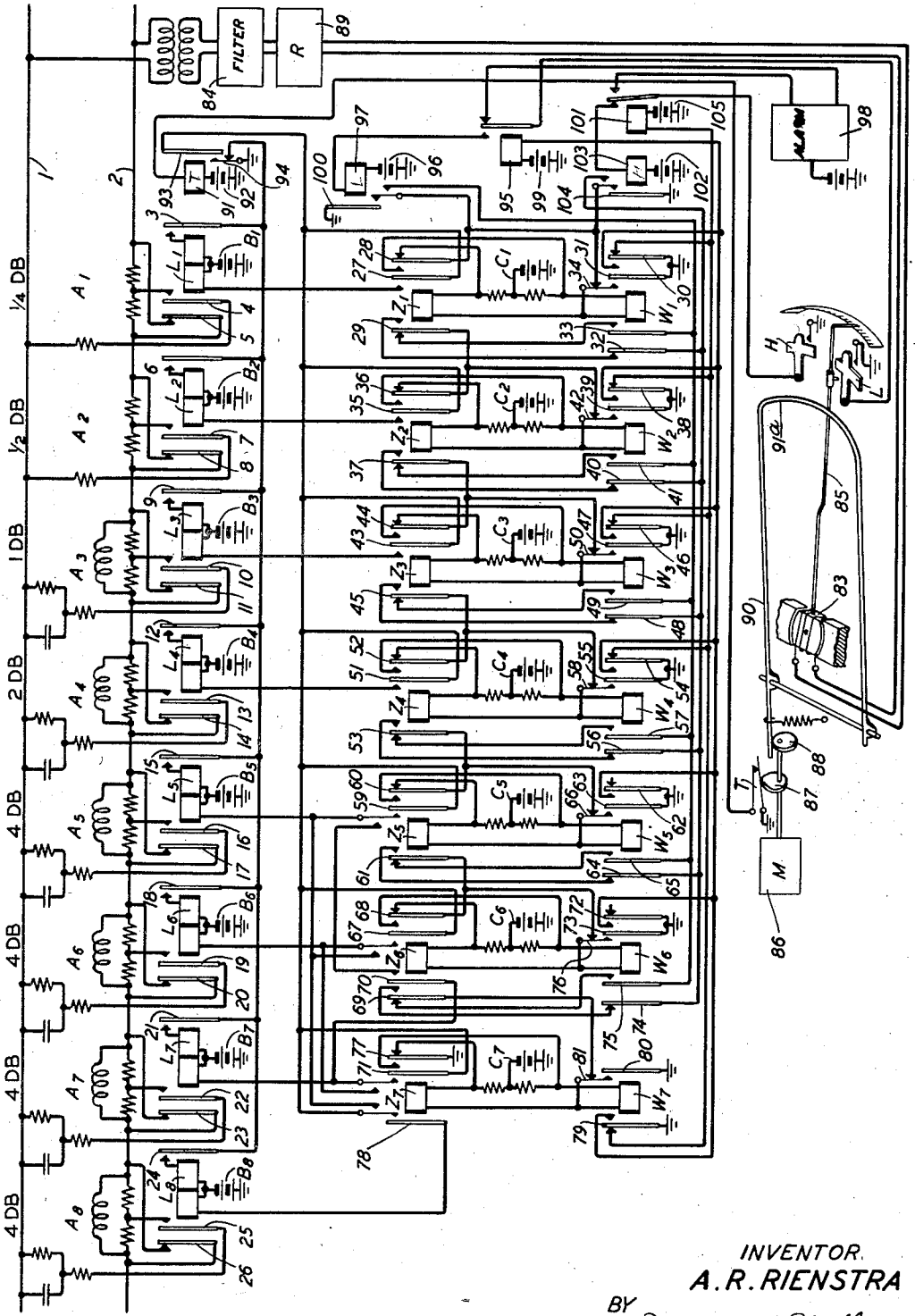

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SIGNAL TRANSMISSION LINE

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This invention relates to signal transmission lines and particularly to regulating circuits for signal transmission lines.

One object of the invention is to provide a signal transmission line with a train of relays for controlling the gain at a repeater station in an improved manner.

Another object of the invention is to provide control circuits at a repeater station on a transmission line with a plurality of pairs of relays controlled according to the energy level of the signals on the line that shall effect functions in number according to a geometric ratio in controlling attenuation pads to govern the gain at the repeater station.

A further object of the invention is to provide a repeater station on a transmission line with a number of attenuation pads increasing in attenuation in a geometric progression and a number of pads having equal attenuation and with a plurality of pairs of control relays that shall effect functions in number according to a geometric ratio in controlling the attenuation pads to govern the gain at the repeater station.

In the transmission of signals over a transmission line changes in the attenuation of the transmitting medium are caused by changes in different conditions as, for example, changes in the weather. In order to obtain good transmission of the signals, correction must be made for the changes in attenuation of the transmitting medium so as to maintain the transmission equivalent of the line substantially constant.

In accordance with the present invention all or a number of the repeater stations on a transmission line are provided with attenuation pads for controlling the gain. The attenuation of a number of the pads at each repeater station increases in accordance with a geometric progression and a number of the pads have equal attenuation. In the circuits employed for describing the invention, eight attenuation pads are provided. The attenuation of the first five pads increases from a quarter decibel attenuation by a geometric progression to four decibels. Each of the last three attenuation pads have an attenuation of four decibels.

The attenuation pads are directly controlled by a series of pad relays, one relay being provided for controlling each attenuation pad. The circuits for operating the pad relays are partially completed by means of a plurality of pairs of control relays. The control relays are operated in accordance with the energy level of the signals or a pilot current on the transmission line. The operating circuits for the pad relays are completed by means of a time relay which is energized and operated at regular intervals.

The pairs of control relays are arranged to effect functions in number according to a geometric ratio. Moreover, the relays in each pair operate and release in a fixed sequence. A high level relay and a low level relay which are operated in accordance with the energy level of the currents on the transmission line are provided for governing the operation of the control relays. For each operation of the high level relay or the low level relay the first pair of control relays is either operated or released. For every other operation of the high level relay or the low level relay the second pair of control relays is either operated or released. The remaining control relays operate in a like manner. The high level relay and the low level relay may be controlled by a pilot current on the transmission line or may be controlled by the signal currents. The signal currents may be within the voice frequency range or may be carrier currents having a much higher frequency range.

If all the attenuation pads are out of the transmission line and the energy level of the signals on the line is above normal, the high level relay is operated for effecting operation of the first pair of control relays. The first pair of control relays prepares a circuit for operating the first pad relay. The circuit for operating the first pad relay is completed by the timing relay for inserting the quarter decibel pad in the line. If the energy level of the signals on the line is not corrected by the first pad the high level relay is again operated and the second one half decibel pad is inserted in the line and the quarter decibel pad taken out of the line. Such operation of the control circuits continues until the correct attenuation is inserted in the line. If the energy level of the signals on the line falls below normal, the low level relay is operated for withdrawing impedance from the line by quarter decibel steps. If the attenuation range of the pads is insufficient to correct the energy level of the signals, an alarm is sounded.

The single figure in the accompanying drawing is a diagrammatic view of control circuits located at a repeater or terminal station and constructed in accordance with the invention.

Referring to the drawing a repeater station on a transmission line comprising conductors 1 and 2 is provided with attenuation pads A_1, A_2, A_3, A_4, A_5, A_6, A_7 and A_8. The pads A_1 to A_5, inclusive, increase in attenuation according to a geometric

progression. Pad A_1 has one quarter decibel attenuation and the pad A_5 has four decibels attenuation. The pads A_6, A_7 and A_8 each have four decibels impedance. A plurality of pad relays L_1, L_2, L_3, L_4, L_5, L_6, L_7 and L_8 are provided for inserting and excluding the attenuation pads in and from the line circuit. The pad relay L_1 is provided with armatures 3, 4 and 5. The relay L_2 is provided with armatures 6, 7 and 8. The relay L_3 is provided with armatures 9, 10 and 11. The relay L_4 is provided with armatures 12, 13 and 14. The relay L_5 is provided with armatures 15, 16 and 17. The relay L_6 is provided with armatures 18, 19 and 20. The relay L_7 is provided with armatures 21, 22 and 23. The relay L_8 is provided with armatures 24, 25 and 26.

A plurality of pairs of control relays Z_1 to Z_7, inclusive, and W_1 to W_7 inclusive, are provided for governing the operation of the pad relays L_1 to L_8, inclusive, to control the attenuation in the line circuit at the repeater station. The control relays are governed in accordance with the energy level of a pilot current at the repeater station.

The pairs of control relays effect functions in number according to a geometric ratio. The term "function" as used in the specification is intended to cover the operating or the releasing of a relay. The pair of relays comprising relays Z_1 and W_1 operate or release every time a change is made in the arrangement of attenuation pads. The second pair of control relays comprising the relays Z_2 and W_2 either operate or release every other time a change is made in the arrangement of attenuation pads. The third set of control relays comprising the relays Z_3 and W_3 function every fourth time a change is made in the arrangement of attenuation pads. The remaining pairs of control relays operate in a like manner according to the geometric ratio. It is understood that a change would have to be in a continuous direction to follow the geometric ratio. In other words, the pads would have to be continuously inserted in the line or continuously withdrawn from the line and not inserted and withdrawn from the line.

The control relay Z_1 is provided with armatures 27, 28 and 29. The relay W_1 is provided with armatures 30, 31, 32 and 33. A movable contact member 34 is controlled by the armature 31 of the relay W_1. The relay Z_2 is provided with armatures 35, 36 and 37. The relay W_2 is provided with armatures 38, 39, 40 and 41. A movable switch member 42 is controlled by the armature 39 of the relay 42. The relay Z_3 is provided with armatures 43, 44 and 45. The relay W_3 is provided with armatures 46, 47, 48 and 49. A movable switch member 50 is controlled by the armature 47 and the relay W_3. The relay Z_4 is provided with armatures 51, 52 and 53. The relay W_4 is provided with armatures 54, 55, 56 and 57. A movable switch member 58 is controlled by the armature 55 of the relay W_4. The relay Z_5 is provided with armatures 59, 60 and 61. The relay W_5 is provided with armatures 62, 63, 64 and 65. A movable switch member 66 is controlled by the armature 63 of a relay W_5. The relay Z_6 is provided with armatures 67, 68, 69 and 70. The relay W_6 is provided with armatures 72, 73, 74 and 75. A movable switch member 76 is controlled by the armature 73 of the relay W_6. The relay Z_7 is provided with armatures 71, 77 and 78. The relay W_7 is provided with an armature 79 and an armature 80. The armature 80 controls a movable switch member 81.

The pairs of control relays are governed in accordance with the operation of a galvanometer 83 which is connected to the line conductors 1 and 2 by means of a filter 84 and a rectifier 89. The filter 84 is selective of the pilot current employed for controlling the gain at the repeater stations. The galvanometer 83 operates a pointer 85 above high contact members H and low contact members L. If the energy level of the pilot current on the line is above normal, the galvanometer arm 85 will be over the contact members H and if the energy level of the pilot current on the line is below normal, the arm 85 of the galvanometer will be positioned above the contact members L. A constant speed motor 86 of any suitable type has two cam members 87 and 88 mounted on the armature shaft thereof. The cam member 87 closes timing contacts T at regular intervals. The cam member 88 engages a lever 90 having an arc-shaped portion 91*a* positioned above the arm 85 of the galvanometer 83. The lever 90 is pivotally mounted so that each time the cam member 88 is operated the arc-shaped portion 91*a* thereof is moved downwardly and engages the arm 85 of the galvanometer 83. When the arm 85 of the galvanometer 83 is moved downwardly, contacts H or contacts L are closed if the arm is positioned above either of said contacts. The cam members 87 and 88 are so positioned on the armature shaft of the motor 86 that the contact members T are never closed at the same time the contact members H or the contact members L are closed.

The T contacts when operated by the cam member 87 complete a circuit from battery 92 for energizing the time relay 91. The time relay 91 is provided with an armature 93 which controls a movable grounded contact member 94. The time relay 91 serves to complete circuits partially completed by the control relays for operating the pad relays.

The low level contact members L when closed with a relay 95 operated complete a circuit from a battery 96 for operating a low level relay 97. If the relay 95 is released when the low level contacts L are closed, a circuit is completed for operating an alarm 98. The relay 95 is energized from a battery 99 whenever any of the W relays are operated. The low level relay 97 is provided with an armature 100.

The high level contact members H when closed with a relay 101 operated complete a circuit from battery 102 for operating the high level relay 103. The high level relay 103 is provided with an armature 104. If the contacts H are closed when the relay 101 is released, a circuit is completed for operating the alarm 98. The relay 101 is energized from a battery 105 whenever any of the W relays are in released position.

Assuming all pads A_1 to A_8, inclusive, to be out of the line, all relays to be deenergized except the relay 101 which is operated whenever a W relay is released and the H contacts to be closed by the galvanometer 83 and the cam member 88, a circuit is completed from the battery 102 for operating the relay 103. The relay 103 upon operation completes a circuit from ground through the armature 104, switch member 34, coil of the relay W_1, battery C_1 and ground return to the armature 104. The relay W_1 is operated and the armature 31 completes a circuit from the battery C_1 for holding the relay W_1 in operative position. The armature 30 of the relay W_1 completes a circuit from battery 99 for operating the relay 95. The relay 95 is operated

at this time so that the low level relay 97 may be operated at any time the L contacts are closed for reducing the attenuation in the line.

The Z_1 relay is not operated at the same time as the W_1 relay because both terminals of the coil of the Z_1 relay are grounded. When the cam member 88 operates the lever 90 for opening the H contacts the circuit energizing the high level relay 103 is opened. Relay 103 is released and the ground applied to the right terminal of the Z_1 relay is removed. The Z_1 relay is then operated by a circuit extending from ground through the armature 31, switch member 34, coil of the relay Z_1, battery C_1 and ground return to the armature 31. The armature 27 of the Z_1 relay prepares a circuit from battery B_1 for operating the L_1 relay. The armatures 28 and 29 of the Z_1 relay complete no circuits at this time. The time contacts T are then closed by the operation of the cam member 87. The closing of the contact members T completes a circuit from the battery 92 for operating the time relay 91. The time relay 91 completes a circuit for operating the L_1 relay to insert the pad A_1 in the line. The circuit completed by the time relay 91 extends from grounded battery B_1 through a coil of the L_1 relay, armature 27 of the Z_1 relay, armature 93 of the time relay, contact member 94 and ground return to the battery B_1. The armature 3 of the L_1 relay completes a holding circuit from the battery B_1 for the L_1 relay when the time relay 91 is released. The armatures 4 and 5 of the L_1 relay insert the quarter decibel pad A_1 in the line circuit.

If the energy level of the signals on the line is not reduced to normal by the insertion of the pad A_1 in the line, the contact members H are again closed for operating the high level relay 103. The operation of the relay 103 grounds the right terminal of the W^1 relay by means of the armature 104. The W_1 relay releases and completes a circuit for operating the W_2 relay. The circuit for operating the W_2 relay may be traced from the armature 104 through armature 32 of relay W_1, armature 29 of relay Z_1, contact member 42, coil of the relay W_2, battery C_2, and ground return to the armature 104. The relay Z_2 does not operate at this time inasmuch as both terminals of the coil thereof are connected to ground. Upon release of the 103 relay when the H contacts are opened, the relay Z_2 is operated by a circuit extending from the battery C_2 through the coil of the Z_2 relay, contact member 42, armature 39 of the W_2 relay and ground return to the battery C_2. At this time a holding circuit for the W_2 relay extends from the battery C_2 through the coil of the W_2 relay, contact member 42, armature 39 and ground return to the battery C_2. When the relay 103 is released, Z_1 relay is released because ground is removed from the terminal of the operating coil therefor. The release of the Z_1 relay insures the release of the L_1 relay when the time relay 91 is next operated. When the L_1 relay is released, the quarter decibel pad A_1 is removed from the line.

The operation of the Z_2 control relay prepares a circuit from battery B_2 for operating the L_2 relay to insert the one half decibel pad A_2 in the line. The operation of the time relay 91 by the T contacts opens the circuit of the L_1 relay and completes a circuit for operating the L_2 relay. The circuit completed by the armature 93 of the time relay 91 extends from the battery B_2 through a coil of the L_2 relay, armature 35 of the Z_2 relay, armature 93 of the time relay 91, switch member 94 and ground return to the battery B_2. The relay L_2 when operated inserts the half decibel pad A_2 in the line. The release of the relay L_1 removes the half decibel pad A_1 from the line so that the attenuation in the line has been increased by one quarter decibel.

Assuming the energy level of the line to fall below normal when the relays Z_2, W_2 and L_2 are operated and the one half decibel pad A_2 is in the line, then the L contacts are closed for reducing the attenuation in the line. The closure of the L contacts completes a circuit from the battery 96 for operating the low level relay 97. The armature 100 of the relay 97 completes a circuit from the battery C_1 for operating the W_1 relay. The circuit for operating the W_1 relay extends from the battery C_1 through the coil of the W_1 relay, switch member 34, armature 100 of the relay 97 and ground return to the battery C_1. The Z_1 relay is not operated at this time because ground is connected to both terminals of the energizing coil thereof. The armature 33 of the W_1 relay completes a circuit for applying ground to the right terminal of the W_2 relay which releases. The release of the W_2 relay does not open the holding circuit for the Z_2 relay. The holding circuit for the Z_2 relay is opened upon release of the relay 97. The Z_1 relay is operated upon release of the relay 97. The relay 97 is released by separation of the L contact members.

The operation of the Z_1 relay prepares a circuit by operation of the armature 27 for operating the L_1 relay. The next operation of the time relay 91 by the time contacts T opens the holding circuit for the relay L_2 which releases and completes an operating circuit for the L_1 relay. The L_1 relay upon operation inserts a quarter decibel pad A_1 in the line and the L_2 relay when released withdraws the half decibel pad from the line. Thus, the attenuation of the line has been reduced by a quarter decibel step.

Assuming the Z_2 relay and the W_2 relay to be operated and the half decibel pad A_2 to be in the line and the H contact members to be closed by reason of the energy level on the line being above normal, the high level relay 103 is operated. The operation of the relay 103 operates the W_1 relay, the Z_1 relay and the L_1 relay in the same manner as described when assumption was made that no pads were in the line and the H contacts were closed. When the Z_1 relay and W_1 relay are operated and the time relay 91 is operated by the T contacts, then a circuit is completed for operating the L_1 relay which inserts the quarter decibel pad A_1 in the line. At this time the Z_2, W_2 and L_2 relays are operated and the half decibel pad A_2 is in the line.

Assuming the Z_1, W_1, Z_2, W_2, L_1 and L_2 relays to be operated and the energy level on the line to be above normal so that the H contacts are again closed, the high level relay 103 is operated. The armature 104 of the relay 103 applies ground to the right terminal of the energizing coil of the W_1 relay which releases. The release of the W_1 relay applies ground from the armature 104 of the relay 103 through armature 32 of the relay W_1, armature 29 of the relay Z_1 and armature 36 of the relay Z_2 to the upper terminal of the relay W_2. The relay W_2 then releases. The release of the relay W_2 completes a circuit from the armature 104 through the armature 40 of the relay W_2, armature 37 of the relay Z_2, contact member 50, the coil of the W_3 relay, battery C_3 and ground return to the armature 104. The relay W_3 is operated. The relay Z_3 is not operated at this time because both terminals of the coil

thereof are connected to ground. When the relay 103 is deenergized by separation of the H contacts, the Z_1 and the Z_2 relays are released by breaking of the circuits from batteries C_1 and C_2, through the operating coils of the Z_1 and Z_2 relays. The Z_3 relay is energized at this time by a circuit extending from the battery C_3 through the operating coil for the relay Z_3, contact member 50, armature 47 and ground return to the battery C_3. The armature 43 of the Z_3 relay prepares a circuit from the battery B_3 to operate the L_3 relay. The circuit for operating the L_3 relay is completed by the time relay 91 when the T contacts are closed. The circuit for operating the L_3 relay extends from the battery B_3 through a coil of the L_3 relay, armature 43, armature 93, contact member 94 and ground return to the battery B_3. The one decibel pad A_3 is inserted in the line upon operation of the L_3 relay. The time relay 91 not only operates the L_3 relay for inserting the A_3 pad in the line, but also releases the L_1 and L_2 relays for withdrawing the A_1 and A_2 pads from the line.

If the energy level of the signals on the line is still above normal value with the A_3 pad in the line and the Z_3 and W_3 relays operated, the H contacts are again closed for operating the high level relay 103. The relay 103 when operated under the above conditions effects operation of the Z_1 and W_1 relays in the manner above set forth. The Z_1 relay when operated prepares a circuit for operating the L_1 relay which is operated upon operation of the time relay 91 by the time contacts T. The L_1 relay inserts the A_1 pad in the line with the A_3 pad.

If the H contacts are again closed at this time the relay 103 is operated for effecting operation of the Z_2 relay and the W_2 relay and the release of the Z_1 relay and the W_1 relay. The Z_2 relay prepares a circuit for operating the L_2 relay so that upon operation of the time relay 91 by the T contacts, the L_2 relay is operated and the L_1 relay is released. The operation of the L_2 relay adds the A_2 pad in circuit with the A_3 pad and the release of the L_1 relay withdraws the A_1 pad from the line. The A_2 and the A_3 pads in the line have an attenuation of one and one half decibels.

If the H contacts are again closed by reason of the energy level of the signals on the line being above normal, the high level relay 103 is again operated for effecting operation of the Z_1 and the W_1 relays in the manner above set forth. The Z_2, W_2 and the Z_3 and the W_3 relays as well as the L_2 and L_3 relays are held in an operated position at this time. The Z_1 relay prepares a circuit for operating the L_1 relay. The time relay 91 operated by the T contacts completes the operating circuit for the L_1 relay for operating the L_1 relay to insert the A_1 pad in the line. At this time the A_1, A_2 and A_3 pads are on the line so that the attenuation of the pads in the line is one and three-quarters decibels.

If the H contacts are again closed by reason of the high energy level of the line, the high level relay 103 is operated. The armature of the high level relay 103 places a ground upon the upper terminal of the relay W_1 so that the relay W_1 releases. The release of the W_1 relay completes a ground circuit for the right terminal of the W_2 relay which extends from the armature 104 through the armature 32, armature 29 and armature 36 to the right terminal of the relay W_2. The W_2 relay upon releasing connects a ground circuit to the right terminal of the coil for the W_3 relay. The circuit connecting ground with the right terminal of the W_3 relay extends from the grounded armature 104 through armature 40 of the relay W_2, armature 37 of the relay Z_2 and armature 44 of the relay Z_3 to the right terminal of the coil of the W_3 relay. The relay W_3 upon releasing completes a circuit for operating the W_4 relay. The circuit for operating the W_4 relay extends from battery C_4 through the coil of the W_4 relay, contact member 58, armature 45 of the Z_3 relay, armature 48 of the W_3 relay, armature 104 of the 103 relay and ground return to the battery C_4. The W_4 relay upon operation establishes a holding circuit for itself through the armature 55. The Z_4 relay is not operated at this time because both terminals of the energizing coil thereof are connected to ground. When the high level relay 103 is released by separation of the contact members H, the Z_4 relay is operated from the battery C_4 through the armature 55 of the W_4 relay. At the same time the Z_1, Z_2 and Z_3 relays are released. The Z_4 relay prepares a circuit for operation of the L_4 relay. Upon operation of the time relay 91, the L_4 relay is operated by a circuit extending from the battery B_4 through the coil of the L_4 relay, armature 51, armature 93, contact member 94 and ground return to battery B_4. The operation of the L_4 inserts the two decibels pad A_4 in the line. At the same time the operation of the time relay 91 releases the L_1, L_2 and L_3 relays to withdraw the A_1, A_2 and A_3 pads from the line.

If the H contacts are again closed the Z_1, W_1 and L_1 relays are operated for inserting the quarter decibel pad A_1 in the line. If the H contacts are again closed the Z_2 and W_2 relays are operated to insert the half decibel A_2 pad in the line while the Z_1, W_1 and L_1 relays are released to withdraw the quarter decibel pad A_1 from the line. The next operation of the H contacts serves to operate the Z_1, W_1 and L_1 relays to insert the quarter decibel pad A_1 in circuit with the A_2 and A_4 pads. The next operation of the H contacts operates the Z_3, W_3 and L_3 relays to insert the one decibel pad A_3 in circuit with the two decibel pad A_4, at the same time the relays Z_1, W_1, Z_2, W_2, L_1 and L_2 are released to withdraw the A_1 and A_2 pads from the line.

With the pads A_3 and A_4 in the line producing three decibel attenuation and the relays L_3, L_4, Z_3, W_3, Z_4 and W_4 operated, the contacts H are again closed if the energy level on the line is above normal. The high level relay 103 is operated to insert the quarter decibel pad A_1 in the line. The next operation of the high level relay 103 by the H contacts inserts the half decibel pad A_2 in the line and withdraws the quarter decibel pad A_1. The next operation of the high level relay 103 by the H contact inserts the quarter decibel pad A_1 in the line. At this time the pads A_1, A_2, A_3 and A_4 are in the line producing three and three-quarter decibel attenuation.

If the high level relay 103 is again operated by the H contacts, the circuit grounded by the armature 104 of the relay 103 places ground on the right terminal of the coil for the W_1 relay. The W_1 relay releases. The armature 32 of the W_1 relay then effects release of the W_2 relay. The armature 40 of the W_2 relay then effects release of the W_3 relay. The W_3 relay by means of its armature 48 effects release of the W_4 relay. Upon release of the W_4 relay a circuit is completed through the armature 56 for effecting operation of the W_5 relay. The W_5 relay upon operation completes a holding circuit from the battery C_5 through the armature 63. The Z_5 relay is not

operated at this time inasmuch as a grounded circuit is connected to each terminal of the coil of the relay. Upon release of the 103 relay by separation of the H contacts the relays Z_1, Z_2, Z_3 and Z_4 are released and the Z_5 relay is operated. The operation of the Z_5 relay prepares a circuit from the battery B_5, through the armature 59 for operating the L_5 relay upon the next operation of the time relay 91. The operation of the time relay 91 by the T contacts releases the L_1 relay, the L_2 relay, the L_3 relay and the L_4 relay to withdraw the pads A_1, A_1, A_3 and A_4 from the line. The relay L_5 is operated to insert the pad A_5 in the line.

The pad A_5 inserts an attenuation of four decibels in the line. The relays L_5, Z_5 and W_5 are operated at this time. The next operation of the H contacts effects operation of the Z_1, W_1 and L_1 relays to insert the A_1 pad in circuit with the A_5 pad. If the H contacts are again operated by reason of high energy level on the line, the Z_2, W_2 and L_2 relays operate to insert the A_2 pad in the line and the Z_1, W_1 and L_1 relays release to withdraw the A_1 pad from the line. The next operation of the H contacts effects operation of the Z_1, W_1 and L_1 relays to insert the A_1 pad in circuit with the A_2 and A_5 pads. At this time four and three-quarter decibels impedance is in the line. The next closure of the H contacts effect operation of the Z_3, W_3 and L_3 relays to insert the A_3 pad in the line and the release of the Z_1, W_1, L_1, Z_2, W_2 and L_2 relays to withdraw the A_1 and the A_2 pads from the line. The next closure of the H contacts effects operation of the Z_1, W_1 and L_1 relays to insert the A_1 pad in the line. The next closure of the H contacts effects operation of the L_2, Z_2 and W_2 relays to insert the A_2 pad in the line and release of the Z_1, W_1 and L_1 relays to withdraw the A_1 pad from the line. The next operation of the H contacts operates the Z_1, W_1 and L_1 relays to insert the A_1 pad in circuit with the A_2, A_3 and A_5 pads. The next closure of the H contacts effects operation of the Z_4, W_4 and L_4 relays to insert the A_4 pad in the line and the release of the Z_1, W_1, L_1, Z_2, W_2, L_2, Z_3, W_3 and L_3 relays to withdraw the A_1, A_2 and A_3 pads from the line.

The next closure of the H contacts effects operation of the Z_1, W_1 and L_1 relays to insert the A_1 pads in the line. The next closure of the H contacts operates the Z_2, W_2 and L_2 relays to insert the A_2 pad in the line and the release of the Z_1, W_1 and L_1 relays to withdraw the A_1 pad from the line. The next closure of the H contacts operates the L_1, W_1 and Z_1 relays to insert the A_1 pad in the line. The next closure of the H contacts operates the Z_3, W_3 and L_3 relays to insert the A_3 pad in the line and the release of the Z_1, W_1, L_1, Z_2, W_2 and L_2 relays to withdraw the A_1 and the A_2 pads from the line. The next closure of the H contacts operates the Z_1, W_1 and the L_1 relays to insert the A_1 pad in the line. The next closure of the H contacts operates the Z_2, W_2 and L_2 relays to insert the A_2 pad in the line and the release of the Z_1, W_1 and L_1 relays to withdraw the A_1 pad from the line. The next closure of the H contacts operates Z_1, W_1 and L_1 relays to insert the A_1 pad in the line. At this time the A_1, A_2, A_3, A_4 and A_5 pads are in the line to produce an impedance of seven and three-quarters decibels.

If the H contacts are again operated with the attenuating pads A_1 to A_5, inclusive, in the line, the high energy level relay 103 is operated to release the W_1 relay. The armature 32 of the W_1 relay effects release of the W_2 relay. The armature 40 of the W_2 effects the release of the W_3 relay. The armature 48 of the W_3 relay effects release of the W_4 relay. The armature 56 of the W_4 relay effects release of the W_5 relay. Upon release of the W_5 relay, the armature 64 completes a circuit for operating the W_6 relay from the battery C_6. The circuit for operating the W_6 relay may be traced from the battery C_6 through the coil of the W_6 relay, contact member 76, armature 61 of the Z_5 relay, armature 64 of the W_5 relay, armature 104 of the 103 relay and ground return to the battery C_6. The Z_6 relay is not operated at this time by reason of both terminals of the coil thereof being grounded. Upon release of the 103 relay, the Z_1, Z_2, Z_3, Z_4 and Z_5 relays are released and the Z_6 relay is operated. The Z_6 relay is operated by circuit from battery C_6 through the coil of the relay, contact members 76, armature 73 of the W_6 relay and ground return to the battery C_6. Upon operation of the relay 91, the L_1, L_2, L_3 and L_4 relays are released to withdraw the pads A_1, A_2, A_3 and A_4 from the line. The L_5 relay is maintained operated and a circuit is completed for operating the L_6 relay. The L_5 relay maintains the A_5 pad in the line and the L_6 relay inserts the A_6 pad in the line so that the attenuation in the line is now eight decibels. The circuit for operating the L_5 relay extends from the battery B_5 through a coil of the L_5 relay, armature 67 of the Z_6 relay, armature 93 of the time relay 91, contact member 94 and ground return to the battery B_5. The circuit for operating the L_6 relay extends from battery B_6 through a coil of relay, armature 67 of the relay Z_6, armature 93 of the time relay 91, contact member 94 and ground return to the battery B_6.

The continued operation of the H contacts effects operation of the control relays Z_1 and Z_4, inclusive, and relays W_1 to W_4, inclusive, to insert the A_1 to A_4 pads in the line with the A_5 and A_6 pads. With the A_1 to A_6 pads in the line, the impedance is eleven and three-quarters decibels. The next operation of the H contacts in the customary manner releases the W_1 relay which releases the W_2 relay, the W_2 relay releases the W_3 relay, and the W_3 relay releases the W_4 relay. The armature 56 of the W_4 relay completes a circuit for operating the W_5 relay. The circuit completed for operating the W_5 relay extends from the battery C_5 through the coil of the W_5 relay, a contact member 66, armature 53 of the Z_4 relay, armature 56 of the W_4 relay, armature 104 of the 103 relay and ground return to the battery C_5. The W_5 relay is operated but the Z_5 relay is not operated until the release of the 103 relay. The release of the 103 relay effects release of the Z_1, Z_2, Z_3 and Z_4 relays. The Z_5 relay prepares a circuit for operating the L_7 relay. Upon operation of the relay 91 by the time contacts T, the relays L_1, L_2, L_3 and L_4 are released to withdraw the pads A_1, A_2, A_3 and A_4 from the line. The L_5 and L_6 relays are held in operated position by reason of the Z_6 being held operated. The L_7 relay is operated by a circuit extending from the battery B_7, armature 70 of the relay Z_6, armature 59 of the relay Z_5, armature 93 of the time relay 91, contact member 94 and ground return to the battery B_7. At this time the relays L_5, L_6 and L_7 are operated to insert the A_5, A_6 and A_7 pads in the line. The pads A_5, A_6 and A_7 have an attenuation of 12 decibels.

If the H contacts are operated continuously by reason of high energy level on the line with the A_5, A_6 and A_7 pads in the line, the A_1, A_2, A_3 and

A_4 pads will be inserted in the line by one quarter decibel steps as disclosed heretofore. When the A_1 to A_7 pads are inserted in the line, the L_1 to L_7 relays are operated, the Z_1 to Z_6 relays are operated and the W_1 to W_6 relays are operated. With the circuits in such condition the next operation of the H contacts energizes the 103 relay to release the W_1 relay, the W_1 relay releases the W_2 relay, the W_2 relay releases the W_3 relay, the W_3 relay releases the W_4 relay, the W_4 relay releases the W_5 relay and the W_5 relay releases the W_6 relay. The armature 74 of the W_6 relay completes a circuit for operating the W_7 relay. The circuit for operating the W_7 relay extends from the battery C_7 through the coil of the W_7 relay, contact member 81, armature 69 of the Z_6 relay, armature 74 of the W_6 relay, armature 104 of the 103 relay and ground return to the battery C_7. The Z_7 relay is not operated at this time by reason of both terminals of the coil thereof being grounded. The release of the relay 103 effects release of the Z_1, Z_2, Z_3, Z_4, Z_5 and Z_6 relays and effects operation of the Z_7 relay. The circuit for operating the Z_7 relay extends from the battery C_7 through the coil of the Z_7 relay, contact member 81, armature 80 of the W_7 relay and ground return to the battery C_7. Operation of the time relay 91 by the T contacts effects release of the L_1, L_2, L_3 and L_4 relays. The L_5, L_6, L_7 and L_8 relays are held operated by the circuits completed by the Z_7 relay. The circuit for operating the L_5 relay may be traced from the battery B_5 through the coil of the L_5 relay, contact member closed by the armature 78 of the Z_7 relay, armature 93 of the time relay 91, contact member 94 and ground return to the battery B_5. The circuit for operating the L_6 relay may be traced from the battery B_6 through a coil of the relay L_6, armature 71 of the Z_7 relay, armature 93 of the time relay 91, contact member 94 and ground return to the battery B_6. The circuit for operating the L_7 relay may be traced from the battery B_7 through the coil of the relay L_7 armature 71 of Z_7 relay, armature 93 of the time relay 91, contact member 94 and ground return to the battery B_7. The circuit for operating the L_8 relay may be traced from the battery B_8 through the armature 78 of the Z_7 relay, armature 93 of the time relay 91, contact member 94 and ground return to the battery B_8.

The operation of the L_5, L_6, L_7 and L_8 relays inserts the pads A_5, A_6, A_7 and A_8 in the line to produce an attenuation of sixteen decibels. It is apparent at this time that if so desired, the pads A_1, A_2, A_3 and A_4 may be inserted in the line with the pads A_5, A_6, A_7 and A_8 to produce a nineteen and three-quarter decibel attenuation. If all the pads A_1 to A_8, inclusive, are in the line and the H contacts are closed a circuit is completed for operating the alarm 88. The attenuation is withdrawn from the line under the control of the L contacts by one quarter decibel steps in the same manner as the attenuation is added to the line by one quarter decibel steps under the operation of the H contacts. One step has been described heretofore in illustrating the operation of the L contacts in withdrawing the attenuation from the line.

Modifications of the circuits and in the arrangement and location of parts may be made within the spirit and scope of the invention and such modifications are intended to be covered by appended claims.

What is claimed is:

1. In combination, a plurality of pairs of control relays for controlling the gain at a station on a transmission line, means for insuring the operation of the relays by pairs with the operation of the relays of each pair in a predetermined sequence and for insuring the release of the relays by pairs with the release of the relays of each pair in the same sequence, a pair of high level contact members, and means comprising circuits governed by said contact members for controlling said pairs of relays to effect functions the number of which correspond to a geometric progression.

2. In combination, a transmission line having a station, a plurality of attenuation pads adapted to be inserted in the line for controlling the gain at the station, a number of said pads increasing in attenuation according to a geometric progression and a number of said pads having equal attenuations, and means operated according to the energy level of the signals on the line for controlling said pads to change the attenuation at the station by equal attenuation steps.

3. In a signal transmission system, a transmission line, a plurality of attenuation pads adapted to be inserted in the line for controlling the attenuation, a number of said pads increasing in attenuation in a geometric progression and a number of said pads having equal attenuations and means comprising a plurality of sets of relays effecting functions the number of which correspond to a geometric ratio for inserting said pads in the line by equal attenuation steps.

4. In combination, a transmission line having a station thereon, a plurality of attenuation pads for controlling the attenuation at the station, a number of said pads increasing in attenuation in a geometric progression and the remaining pads having equal attenuations, a pad relay for controlling each pad, pairs of control relays for governing said pad relays, and means controlled according to the energy level of a pilot current on the line for operating said control relays to govern the operation of said pad relays and adjust the attenuation in the line at the station by equal attenuation steps.

5. In combination, a plurality of attenuation pads for controlling the attenuation on a transmission line, a number of said pads increasing in attenuation in a geometric progression and the remaining pads having equal attenuations, a pad relay for controlling the operation of each of said pads, pairs of control relays controlling the operation of the pad relays, means for governing said control relays according to the energy level of a pilot current on said line to prepare circuits for operating said pad relays, said control relays effecting functions the number of which correspond to a geometric progression when the attenuation is changed by a number of steps in one direction, and means operated at regular time intervals for effecting operation of the pad relays selected by said control relays.

6. In combination, a transmission line, a plurality of attenuation pads for controlling the attenuation on the line, a pad relay for controlling each of said pads to govern the attenuation on the line, pairs of control relays for partially completing circuits to operate said pad relays, means for controlling said pairs of control relays to effect functions the number of which correspond to a geometric progression, means for effecting operating and releasing of the relays of each pair of control relays in a fixed sequence,

means comprising two pairs of contact members for governing the control relays according to the energy level of a pilot current on the line and means comprising a pair of contact members operated at fixed intervals for completing the pad relay circuits partially completed by the pairs of control relays.

7. In combination, a plurality of attenuation pads for controlling the attenuation on a transmission line, a pad relay associated with each attenuation pad for controlling the insertion and withdrawal of the pads in and out of said line, a plurality of pairs of control relays for preparing circuits to operate said pad relays, means operated at regular time intervals for effecting operation of the pad relays selected by said control relays, means for controlling said pairs of control relays to effect functions thereby the number of which correspond to a geometric progression, means for effecting functioning of the relays of each pair of control relays in a fixed sequence, and means for governing the control relays according to the energy level of a pilot current on the line.

8. In combination, a plurality of attenuation pads for controlling the attenuation on a transmission line, a number of said pads increasing in attenuation in a geometric progression and a number of said pads having equal attenuations, a series of pad relays for controlling the insertion and withdrawal of said pads in and out of said line, a plurality of sets of control relays for preparing circuits for operating said pad relays, said control relays effecting functions the number of which correspond to a geometric ratio when operated for inserting attenuation pads in the line, means for operating said control relays according to the energy level at the repeater station of the currents on the line, and means operated at regular time intervals for effecting operation of the pad relays selected by said control relays to change the attenuation by equal steps.

9. In combination, a plurality of attenuation pads for controlling the attenuation on a transmission line, a pad relay for controlling each of said pads to govern the line attenuation, a pair of control relays for controlling the operating circuit of each of said pad relays, means for controlling the pairs of said control relays according to the energy level on the line, each operated pair of control relays partially completing a circuit for operating the associated pad relay, and means operated at constant intervals for completing the circuits of the pad relays which have been partially completed by the pair of control relays.

10. In combination, a plurality of attenuation pads for controlling the attenuation on a transmission line, a pad relay for controlling each of said pads to govern the line attenuation, a plurality of pairs of control relays for controlling the operation of the pad relays, each pair of control relays when operated partially completing an energizing circuit for a pad relay, means comprising high level contact members and low level contact members for operating said pairs of control relays according to the energy level on the transmission line, and means comprising timing contact members closed at fixed intervals for completing the energizing circuits of the pad relays which have been partially completed by the pairs of control relays and for releasing any operated pad relay when the pair of control relays associated therewith has been released.

11. In combination, a transmission line, a repeater station on said line, a plurality of attenuation pads for controlling the gain at the repeater station, a pad relay for controlling each of said pads, a plurality of pairs of control relays, each of said pairs of relays when operated serving to partially complete an energizing circuit for a pad relay, high level contact members, low level contact members, means for operating said high level contact members when high energy level is on said line to control said pairs of relays and for operating said low level contact members when low energy level is on said line to control said pairs of relays, and means comprising a pair of timing contact members closed at fixed intervals for completing the circuits of the pad relays which have been partially completed by the pairs of control relays.

12. In combination, two series of relays divided into pairs, each of said pairs being formed by one relay from each series of relays, a pair of contact members, and means controlled by the operating and releasing of said pair of contact members for controlling said series of relays so that the pairs of relays effect functions the number of which functions correspond to a geometric progression, the relays operating and releasing by pairs with the relays of each pair operating and releasing in a predetermined sequence.

13. In combination, two series of relays divided into pairs, each of said pairs of relays being formed by one relay from each series of relays, a pair of contact members, and means comprising circuits controlled by the opening and closing of said contact members for operating the first pair of relays and for operating any other selected pair of relays by controlling the pairs of relays back of said selected pair of relays so that the pairs of relays back of the selected pair of relays effect functions the number of which functions correspond to a geometric progression.

14. In combination, two series of relays divided into pairs, each of said pairs of relays being formed by one relay from each series of relays, a pair of high contact members, a pair of low contact members, means comprising circuits controlled by said high contact members for operating the first pair of relays and for operating any other selected pair of relays by controlling the pairs of relays back of said selected pair of relays so that the pairs of relays back of the selected pair of relays effect functions the number of which functions correspond to a geometric progression and controlled by said low contact members for releasing the first pair of relays if operated alone and for releasing another pair of operated relays by controlling the pairs of relays back of the operated pair of relays so that the pairs of relays back of the operated pairs of relays effect functions the number of which functions correspond to a geometric progression.

15. In combination, a transmission line, a plurality of attenuation pads for controlling the attenuation on the transmission line, a number of said pads increasing in attenuation according to a geometric progression and a number of said pads having equal attenuations, means comprising pairs of control relays for controlling said attenuation pads to adjust the attenuation of the line by equal attenuation steps, and means for controlling said pairs of control relays to effect functions the number of which functions correspond to a geometric progression.

16. In combination, a transmission line, a plu-

rality of attenuation pads for controlling the attenuation on the transmission line, a number of said pads increasing in attenuation according to a geometric progression and a number of said pads having equal attenuations, a pad relay for controlling each of said pads, a plurality of pairs of control relays for controlling the operation of said pad relays, each pair of control relays when operated partially completing an energizing circuit for a pad relay, means controlled by the energy level on said line for controlling said pairs of control relays to effect functions the number of which functions correspond to a geometric progression, and means comprising a pair of timing contact members operated at fixed intervals for completing energizing circuits for the pad relays that have been partially completed by the pairs of control relays.

17. In combination, a transmission line, a repeater station on said line, a plurality of attenuation pads for controlling the gain at the repeater station, pairs of control relays for controlling said attenuation pads, a pair of high level contact members, a pair of low level contact members, means for operating said high level contact members in case of high energy level on said line and for operating said low level contact members in case of low energy level on said line, and means comprising circuits controlled by the high level contact members in case of high energy level on said line and by the low level contact members in case of low energy level on said line for effecting functions by said pairs of relays the number of which functions correspond to a geometric progression.

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