

Jan. 18, 1938.

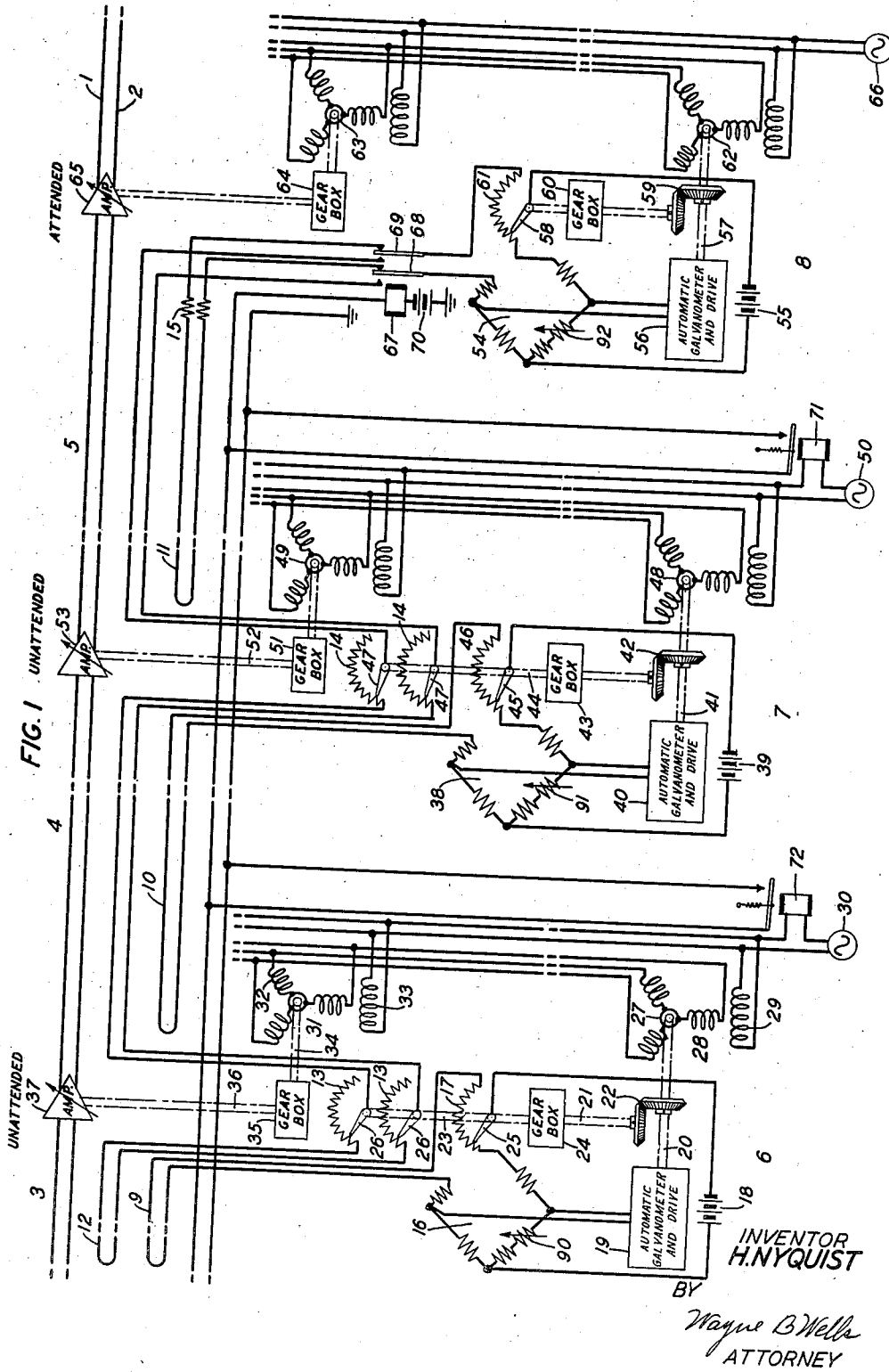
H. NYQUIST

2,105,927

GAIN CONTROL SYSTEM

Filed Nov. 24, 1936

2 Sheets-Sheet 1



Jan. 18, 1938.

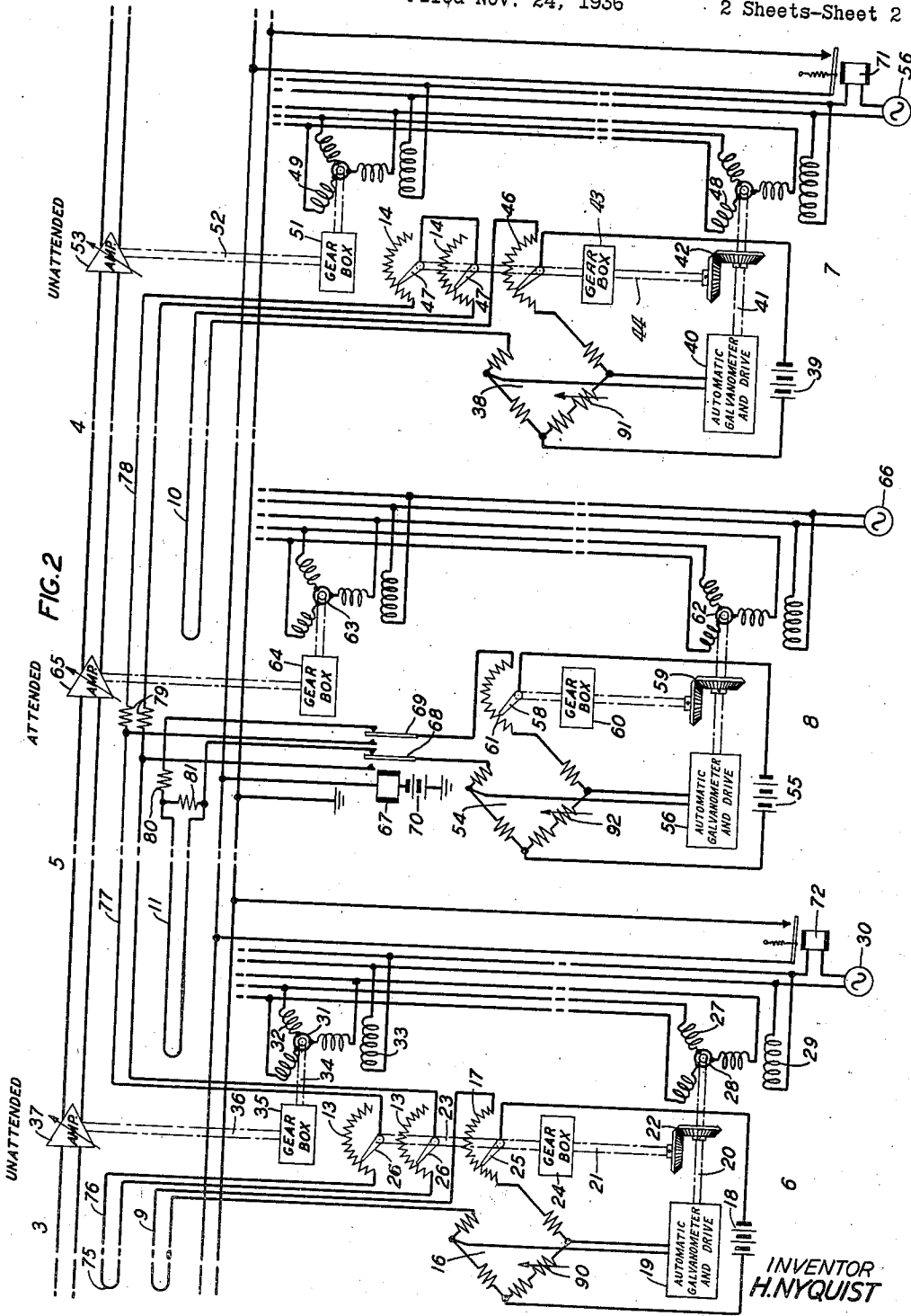
H. NYQUIST

2,105,927

GAIN CONTROL SYSTEM

Filed Nov. 24, 1936

2 Sheets-Sheet 2



INVENTOR
H. NYQUIST

BY
Wayne B Wells
ATTORNEY

UNITED STATES PATENT OFFICE

2,105,927

GAIN CONTROL SYSTEM

Harry Nyquist, Millburn, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application November 24, 1936, Serial No. 112,461

14 Claims. (Cl. 178—44)

This invention relates to gain control systems and particularly to gain control systems having a plurality of gain control stations located along a signal transmission line.

5 One object of the invention is to provide a gain control system having a plurality of gain control stations located along a signal transmission line that shall transfer the gain control operation of one station in case of failure in the operation thereof to another station.

10 Another object of the invention is to provide a gain control system having a plurality of gain control stations respectively controlled by normal pilot lines associated with sections of a transmission line that in case of failure of a control station shall transfer the control of another station from the normal pilot line to an emergency pilot line for compensating for line losses in the line sections associated with the two stations.

15 A further object of the invention is to provide a gain control system having an attended gain control station and unattended gain control stations, normal pilot lines respectively associated with sections of a transmission line and an emergency pilot line associated with all sections of the transmission line that shall govern the stations according to the resistance variations of the normal pilot lines while maintaining constant the resistance of the portions of emergency pilot line associated with the unattended stations and that shall transfer the control of the attended station from the normal pilot line to the emergency pilot line in case of failure of an unattended station.

20 In a signal system for example a cable carrier system it is necessary to provide gain control stations at intervals along a transmission line in order to control the strength of the signals. The gain control stations are each intended to take care of the attenuation on a section of the transmission line. In one type of gain control system the gain control stations associated with the line sections are respectively controlled by pilot lines extending along the line sections. Each pilot line is subjected to the same resistance varying conditions as the associated line section. The flat gain regulators shown in the patent to F. A. Brooks 2,075,975, April 6, 1937, illustrate a gain control system under the control of pilot lines associated with line sections. In a gain control system of the type disclosed in the F. A. Brooks Patent 2,075,975 certain of the gain control stations are attended and other of the stations are unattended. The stations having a twist regulator associated with the flat gain regulator are

attended whereas the gain control stations having only a flat gain regulator are unattended.

Each of the gain control stations in the system disclosed in the F. A. Brooks Patent 2,075,975, April 6, 1937, are operated by means of a source of power. If the source of power at any gain control station fails for any reason the gain control operation at the station where power failure occurs may be interrupted. At an attended station another source of power may be easily provided so that the gain control operation continues.

10 In accordance with the present invention means are provided whereby a failure of the gain control operation by reason of failure of power at an unattended gain control station may be corrected for by adding the gain control operation of the disabled station to the gain control operation of an attended station. A normal pilot line is associated with each of the line sections for controlling the operation of the gain control stations in accordance with the resistance variations in line sections. One attended station is associated with a number of unattended gain control stations. The gain control apparatus at the attended station may not only be governed according to the resistance variations in a normal pilot line associated with one line section, but may be controlled according to the resistance variations in an emergency pilot line. The emergency pilot line is associated not only with the line section associated with the attended station, but also with the line sections associated with the attended gain control stations.

15 Under normal operating conditions the unattended gain control stations and the attended gain control station are governed in accordance with resistance variations in the normal pilot lines. Unattended gain control stations not only balance the Wheatstone bridge circuits including the normal pilot lines and control the gain control amplifiers at such stations, but also vary resistance elements included in the emergency pilot line. The resistance elements in the emergency pilot line at each unattended station are so varied as to maintain the portions of the emergency pilot line associated with the line sections for unattended stations at constant resistance. In other words, the resistance variations of the emergency pilot line associated with the line sections for unattended stations are compensated for so as to maintain the emergency pilot line resistance constant except for the portion associated with the line section for the attended station. The normal pilot line which controls the gain control operation at the attended station

is provided with a permanent resistance substantially equivalent to the resistance value of the emergency pilot lines associated with the line sections for the unattended gain control stations.

5 The normal pilot line for the attended gain control station and the emergency pilot line are provided with the above-mentioned resistance elements so that the control of the gain at the attended station may be switched from the normal
10 pilot line to the emergency pilot line without interfering with the operation of the gain at the attended station.

In case of failure of the power at an unattended station the gain control operation at this station is stopped and also further change in the resistance of the emergency pilot line at this station is stopped. The failure of the power at an unattended station automatically controls switching means at the attended station for disconnecting the gain control apparatus at the attended
20 station from the normal pilot line and for connecting this gain control apparatus to the emergency pilot line. The emergency pilot line then controls the gain at the attended station not only
25 in accordance with the resistance variations in the line section associated with the attended gain control station, but also in accordance with the resistance variations in the line section associated with the disabled gain control station. At this
30 time it will be apparent that the resistance variations effected in the emergency pilot line at any of the unattended stations which are in operation will prevent any control of the gain control
35 apparatus at the attended station according to the resistance variations in the line sections for the operating unattended stations. When the source of power is returned to the unattended station and the gain control apparatus at the unattended station assumes its normal operation,
40 the control of the gain control apparatus at the attended station will be switched from the emergency pilot line back to the normal pilot line.

In the accompanying drawings,

Fig. 1 is a diagrammatic view of a gain control system constructed in accordance with the
45 invention;

Fig. 2 is a diagrammatic view of a modification of the invention wherein the attended gain control station is located between associated unattended gain control stations.

Referring to Fig. 1 of the drawings a gain control system is shown comprising a signal transmission line having conductors 1 and 2 which are divided into sections 3, 4 and 5. The sections 3,
50 4 and 5 of the transmission line may each be approximately twenty miles in length. The gain on the three line sections 3, 4 and 5 is controlled by three gain control stations 6, 7 and 8. The station 8 is provided with an attendant whereas the two stations 6 and 7 are unattended. A normal pilot line 9 which is associated with the line section 3 controls the operation of the station 6. The pilot line 9 is subjected to the same temperature conditions and resistance varying
60 conditions as the line section 3. A normal pilot line 10 which is associated with the line section 4 is provided for controlling the operation of the station 7. A normal pilot line 11 is provided for controlling the operation of the attended station 8. An emergency pilot line 12 which is associated with the line sections 3, 4 and 5 is provided for controlling the operation of the station 8 under predetermined conditions as will be described hereinafter. Adjustable resistance elements 13 are provided in the emergency pilot
75

line at station 6 and adjustable resistance elements 14 are provided in the emergency pilot line 12 at station 7. The normal pilot line 11 for the station 8 is provided with resistance elements 15 for a purpose to be set forth hereinafter.

The gain control apparatus at station 6 comprises a Wheatstone bridge 16 having one arm thereof formed by the normal pilot line 9. The bridge 16 includes an adjustable resistance 17 which may be operated as hereinafter set forth
10 for rebalancing the bridge. The bridge 16 includes a second adjustable resistance 18 for varying the ratio of the bridge for variations in the characteristic of the cable. A battery 19 is connected across two vertices of the bridge and an
15 automatic galvanometer control mechanism 20 is connected across the other two vertices of the bridge. The galvanometer control mechanism 20 may be of the type disclosed in the above-mentioned patent to F. A. Brooks, 2,075,975. A galvanometer mechanism of the type under consideration is also disclosed in the patent to J. A. Coy et al. No. 2,017,654, dated October 15, 1935. The bridge circuit 16 controls the galvanometer mechanism 20 in accordance with variations of resistance in the normal pilot line 9. The galvanometer control mechanism 20 rotates a shaft 21 in a forward or in a reverse direction according to the variations in resistance of the pilot line 9. The galvanometer control shaft 21 is connected
30 to a shaft 22 by means of beveled gears 23. The shaft 22 is connected to a control shaft 24 by means of reduction gearing 25. An arm 26 operated by the shaft 24 adjusts the resistance 17 to rebalance the bridge 16 for each operation of the galvanometer control mechanism 20. Two switch arms 27 are provided for adjusting the resistance elements 13 in the emergency pilot line 12. The resistance elements 13 are so adjusted under the control of the galvanometer control mechanism 20 that the portion of the emergency pilot line associated with the line section 3 is maintained at constant resistance during the operation of the gain control station 6 by the normal pilot line 9.

The galvanometer control shaft 21 also operates the rotor 27 of a master synchronous motor 28. The stator winding 29 for the motor 28 is energized from a single phase source 30 of alternating current. The master motor 28 may control a number of similar motors synchronously in the manner disclosed in the patent to C. J. A. Michalke No. 684,579 dated October 15, 1901. One service motor 31 is shown at station 6 under control of the master motor 28. The motor 31 comprises a rotor winding 32 which is connected to the rotor winding of the motor 28 and a stator winding 33 which is connected to the source of alternating current 30. The motor 31 when so connected to the master motor 28 will follow the movements of the motor 28 in a forward and in a reverse direction. Accordingly, the motor 31 is operated in accordance with the operation of the galvanometer control mechanism 20 and according to resistance variations in the normal
65 pilot line 9. The rotor shaft 34 of the motor 31 is connected by reduction gears 35 to a shaft 36. The shaft 36 in any suitable manner as for example by the means disclosed in the above-mentioned patent to F. A. Brooks, No. 2,075,975 governs the operation of an amplifier 37. The amplifier 37 controls the gain for the line section 3.

The control station 7 is provided with a Wheatstone bridge 38 which is similar to the Wheat-
75

stone bridge 16 at station 6. The bridge 38 is provided with an adjustable resistance 91 similar to the resistance 90 in the bridge 16 at station 6. The bridge 38 is energized by a battery 39 and controls the operation of galvanometer control mechanism 40 which is similar to the galvanometer control mechanism 19 at station 6. The galvanometer control mechanism 40 by means of a shaft 41, beveled gears 42 and reduction gears 43 operates a shaft 44. The shaft 44 controls a switch arm 45 for adjusting a resistance 46 to rebalance the bridge 38 after each operation of the galvanometer control mechanism 40. The shaft 44 also operates two switch arms 47 for adjusting the resistance elements 14 in the emergency pilot line 12. The resistance elements 14 are adjusted to maintain the resistance constant in that portion of the emergency pilot line associated with the line section 4 when station 7 is in operation under control of the pilot line 10. The galvanometer control shaft 41 also operates a master motor 48 which is similar to the master motor 28 at station 6. The master motor 48 operates a service motor 49 which is similar to the service motor 31 at station 6. The stator windings for the motors 48 and 49 are energized from a suitable source 50 of alternating current. The rotor shaft for the motor 49 is connected through reduction gearing 51 to a shaft 52. The rotation of the shaft 52 controls the gain of an amplifier 53 in any suitable manner as by the means disclosed in the patent to F. A. Brooks, 2,075,975. The amplifier 53 controls the gain on the transmission line for the section 4.

The station 8 is provided with a Wheatstone bridge 54 having one arm thereof formed by the pilot line 11. An adjustable resistance 92 is provided for the bridge 54 which is similar to the resistance 90 for the bridge 16. The bridge 54 is energized by a battery 55 and controls the operation of galvanometer control mechanism 56. The galvanometer control shaft 57 which is rotated in a forward and reverse direction by the galvanometer control mechanism 56 operates a switch arm 58 by means of beveled gears 59 and reduction gearing 60. The switch arm 58 controls a resistance 61 to rebalance the bridge circuit 54. The galvanometer control shaft 57 also operates a master motor 62 which in turn operates a service motor 63. The service motor 63 by means of reduction gearing 64 controls the operation of an amplifier in the same manner as the amplifier 53 is controlled by the service motor 49. The amplifier 65 controls the gain on the line section 5. The stator windings for the master motor 62 and the service motor 63 are energized from a suitable source of alternating current 66.

A relay 67 is provided at the attended station 8 for changing the control of the attended station from the normal pilot line 11 to the emergency pilot line 12 in case of failure of the gain control apparatus at station 6 or station 7 by reason of failure of the power supply 30 or the power supply 50. The relay 67 is provided with two switch arms 68 and 69 which are shown in the released position to connect the normal pilot line 11 to the Wheatstone bridge circuit 54. Upon energization of the relay 67 the switch arms 68 and 69 connect the emergency pilot line 12 to the Wheatstone bridge circuit 54. The relay 67 is energized from the battery 70 by a relay 71 located at the gain control station 7 or by relay 72 located at the gain control station 6. The

relay 71 is energized by the source 50. Upon failure of the source 50 the relay 71 releases to complete a circuit for operating the relay 67. The relay 72 is controlled in a like manner by the source 30. Thus upon failure of the source 30 or the source 50 the relay 72 or the relay 71 is released to energize the relay 67 and switch the control of station 8 from the normal pilot line 11 to the emergency pilot line 12.

The resistance 15 in the normal pilot line 11 at the attended gain control station 8 is equal to the resistance values of that portion of the emergency pilot line 12 which is associated with the line sections 3 and 4. As above set forth the resistance elements 13 and 14 maintain the sections of the emergency pilot line associated with the line sections 3 and 4 at constant resistance values so that a change of the control at the attended station from the normal pilot line to the emergency pilot line will not disrupt the gain control operation.

In case of failure of the gain control station 6 by reason of failure of the power source 30 the relay 72 is released. The release of the relay 72 completes a circuit from the battery 70 for operating the relay 67. The relay 67 upon operation transfers the control of station 8 from the normal pilot line 11 to the emergency pilot line 12. The emergency pilot line 12 will then control the gain at station 8 not only to compensate for resistance variations in line section 5, but also to compensate for resistance variations in line section 3. No compensation, however, will be made for attenuation changes in line section 4 by reason of the operation of the resistance element 14 under control of the galvanometer control mechanism 40. However, if station 7 should fail in the same manner as assumed for station 6 the emergency pilot line 12 will then also control station 8 in accordance with the attenuation variations in line section 4. Upon the return of the source to the disabled station and operation of the disabled station the relay 67 will be released to disconnect the emergency pilot line from the Wheatstone bridge circuit 54 so that control of the attended station 8 will be under control of the normal pilot line 11. If so desired it is apparent that the relays 72 and 71 may operate the relay 67 to produce a signal and inform the attendant at station 8 that the control of station 8 should be shifted from one pilot line to the other pilot line.

The gain control system shown in Fig. 2 is very similar to the gain control system shown in Fig. 1 except that the attended station is positioned intermediate the two unattended stations. Inasmuch as the three stations shown in Fig. 2 are similar to the three stations shown in Fig. 1, like parts have been indicated by similar reference characters and a detailed description of the three stations in Fig. 2 is deemed unnecessary.

The emergency pilot line 75 shown in Fig. 2 of the drawings differs from the emergency pilot line 12 shown in Fig. 1 of the drawings inasmuch as portions thereof are located on each side of the attended station 8. On one side of the attended station 8 a portion 76 of the emergency pilot line is associated with the line section 3 and another portion 77 of the emergency pilot line is associated with the line section 5 and on the other side of the attended station 8 a portion 78 of the emergency line is associated with the line section 4. Resistance elements 79 are provided in the emergency pilot line adjacent to the section 78 to balance the resistance of the sec-

tions 76 and 77 of the emergency pilot line. The normal pilot line 11 for the attended station 8 is provided with a series resistance 80 and a parallel resistance 81 so that the normal pilot line and emergency pilot line will have approximately the same resistance values and no trouble in the operation of the attended station will take place when switching from one pilot line to the other pilot line.

The operation of the gain control system shown in Fig. 2 is exactly the same as the operation of the gain control circuits shown in Fig. 1 and a detailed description of the operation of Fig. 2 is deemed unnecessary. In case of failure of the source 30 at station 6 the relay 72 is released to control the relay 67 in the same manner as above described with reference to the system shown in Fig. 1. The relay 67 switches the control of station 8 from the normal pilot line 11 to the emergency pilot line 75. The emergency pilot line under these conditions controls station 8 not only to take care of the gain for the line section 5 but also to take care of the gain of the line section 3. A similar operation may take place with respect to the unattended gain control station 7.

Modifications in the systems 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 the appended claims.

What is claimed is:

1. In a gain control system, a signal transmission line divided into sections, a main gain control station and auxiliary gain control stations associated with the sections of said transmission line, means at said stations for controlling the gain on the respective sections of the transmission line, emergency means for varying the gain control means at the main station not only to compensate for the loss on the section of the transmission line associated with the main station but also to compensate for the loss on a section of the transmission line associated with an auxiliary station, and means operative at an auxiliary station in case of failure of the gain control means at the auxiliary station for effecting operation of the emergency means.

2. In a gain control system, a signal transmission line divided into sections, a main gain control station and auxiliary gain control stations respectively associated with said line sections, gain control means at each of said stations to compensate for the loss on the associated line section, a source of power for operating each of said gain control means, emergency means for varying the gain control means at the main station not only to take care of the loss on the line section associated with the main station but also to take care of the loss on a line section associated with an auxiliary station, and means operative upon failure of the power for operating the gain control means at an auxiliary station for operating said emergency means.

3. In a gain control system, a transmission line divided into sections, a gain control station associated with each of said line sections, a normal pilot line associated with each of said line sections, an emergency pilot line associated with all of said line sections, control means at each of said stations under control of the associated normal pilot line for governing the gain on the transmission line, and emergency means for changing the control of said control means from the normal pilot line to the emergency pilot line at one of

said stations upon failure of the control means at another one of said stations.

4. In a gain control system, a transmission line divided into sections, an attended gain control station, an unattended gain control station, said stations being respectively associated with line sections, normal pilot lines associated with the line sections for said control stations, an emergency pilot line associated with the line section for both of said stations, means for controlling each gain control station according to the resistance variations of the associated normal pilot line, and means operative upon failure of the unattended station to shift the control of the attended station from the normal pilot line to the emergency pilot line.

5. In a gain control system, a transmission line divided into two sections, an attended gain control station, an unattended gain control station, said stations being associated with different line sections, normal pilot lines associated with the line sections for said control stations, an emergency pilot line associated with the two line sections, power operated means for controlling each gain control station according to the resistance variations of the associated normal pilot line, and means operative upon failure of the power for the power operated means at the unattended station to shift the control of the attended station from the normal pilot line to the emergency pilot line.

6. In a gain control system, a transmission line divided into sections, an attended and two unattended gain control stations respectively provided for said line sections to control the gain on the transmission line, a normal pilot line associated with each of said line sections, an emergency pilot line associated with all of said line sections, means for controlling each gain control station according to the resistance variations of the associated normal pilot line, and means operative upon failure of an unattended station to control the gain on the line to shift the control of the attended station from the normal pilot line to the emergency pilot line.

7. In a gain control system, a transmission line divided into sections, an attended and an unattended gain control station, said stations being respectively associated with different line sections, a normal pilot line associated with each of said line sections, an emergency pilot line associated with all of said line sections, means for controlling each gain control station according to the resistance variations of the associated normal pilot line, means at the unattended station when the station is in operation for maintaining the resistance constant in the portion of the emergency pilot line associated with the line section for the station, and means for changing the control of the attended station from the normal pilot line to the emergency pilot line in case of failure of the unattended station.

8. In a gain control system, a transmission line divided into sections each having a gain control station associated therewith, a normal pilot line associated with each of said line sections, an emergency pilot line associated with all of said line sections, control means at each of said stations operated by a source of power and controlled by the associated pilot line for governing the gain on the transmission line, and means operative upon failure of the power at one of said stations for changing the control means at another station from the normal pilot line to the emergency pilot line.

9. In a gain control system, a transmission line divided into sections and having an attended station and a number of unattended stations respectively associated with different line sections, a normal pilot line associated with each line section, an emergency pilot line associated with all the line sections, control means at each of said stations operated by a power source under control of the associated pilot line for controlling the gain on the transmission line, and means operative upon failure of the power at one of said unattended stations for changing the control means at the attended station from the normal pilot line to the emergency pilot line.

10. In a gain control system, a transmission line divided into sections, a normal pilot line associated with each of said line sections, an emergency pilot line associated with all of said line sections, control means at each of said stations, each control means being under control of the associated normal pilot line for governing the gain on the transmission line, said control means at certain of said stations when in operation serving to maintain the resistance of the emergency pilot line associated with the line section for the station constant, and emergency means for changing the control of the control means from the normal pilot line to the emergency pilot line at a station normally effecting no control of the emergency pilot line upon failure of the control means at one of the stations which normally effects control of the emergency pilot line.

11. In a gain control system, a transmission line divided into sections, a normal pilot line associated with each of said line sections, an emergency pilot line associated with all of said line sections, control means at each of said stations under control of the associated pilot line for governing the gain on the transmission line, resistance control means at all stations except one station for maintaining the resistance constant in the portion of the emergency pilot line associated with the line section for the station having the resistance control means, and emergency means for changing the control of the control means at the station having no resistance control means from the normal pilot line to the emergency pilot line upon failure of the control means at a station having a resistance control means.

12. In a gain control system, a transmission line divided into sections, a normal pilot line associated with each of said line sections, an emergency pilot line associated with all of said line sections, a main gain control station associated with one of said line sections, two auxiliary gain control stations respectively associated with

line sections located on opposite sides of the line section associated with the main station, control means located at each of said stations for governing the gain on the transmission line according to change in the associated normal pilot line, and emergency control means for changing the control of the control means at the main station from the normal pilot line to the emergency pilot line upon failure of the control means at one of the auxiliary stations.

13. In a gain control system, a transmission line divided into sections, a normal pilot line associated with each of said line sections, an emergency pilot line associated with all of said line sections, a main gain control station associated with one of said line sections, two auxiliary gain control stations respectively associated with line sections located on opposite sides of the line section associated with the main station, control means located at each of said stations for governing the gain on the line according to changes in the associated normal pilot line, resistance control means at each of said auxiliary control stations when in operation for maintaining the resistance constant in the portion of the emergency pilot line associated with the auxiliary station, and emergency control means for changing the control of the control means at the main station from the normal pilot line to the emergency pilot line upon failure of the control means at one of the auxiliary stations.

14. In a gain control system, a transmission line divided into sections and having an attended station and a number of unattended stations, a normal pilot line associated with each of said line sections, each of said stations having one of the normal pilot lines connected to it, an emergency pilot line connected to the attended station and extending along each of said line sections, control means at each of said unattended stations governed by the associated pilot line for controlling the gain on the line and for varying a resistance in the emergency pilot line to maintain the resistance of the emergency pilot line associated with the line section for that station constant, means at the attended station governed by the associated pilot line for controlling the gain on the transmission line, a resistance equal to the resistance of the portions of the emergency pilot line associated with line sections controlled by the unattended station being added to the normal pilot line connected to the attended station, and means operated upon failure of a source of power at an unattended station for disconnecting the normal pilot line from the control means at the attended station and for connecting the emergency pilot line to the control means.

HARRY NYQUIST.