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May 1, 1945.

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2,375,051

RADIO RECEIVING SYSTEM

Filed Dec. 7, 1943

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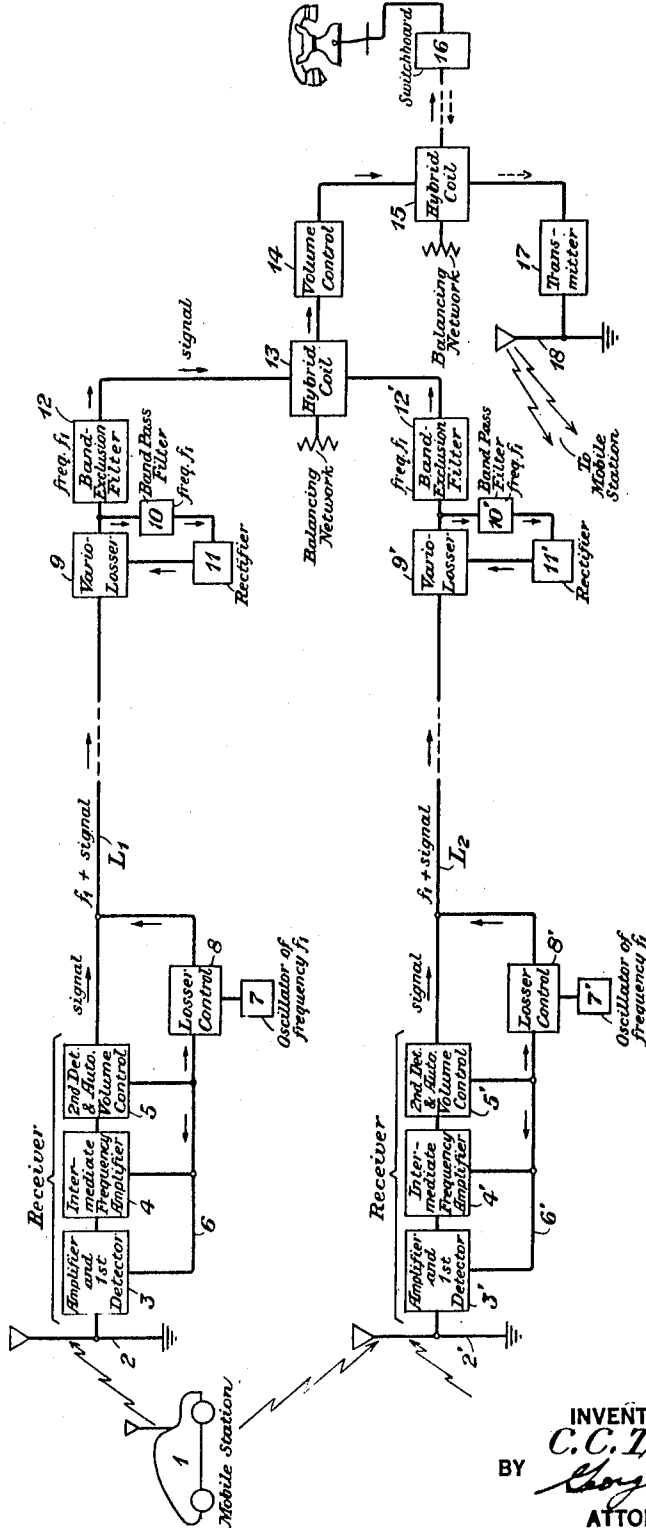


Fig. 1

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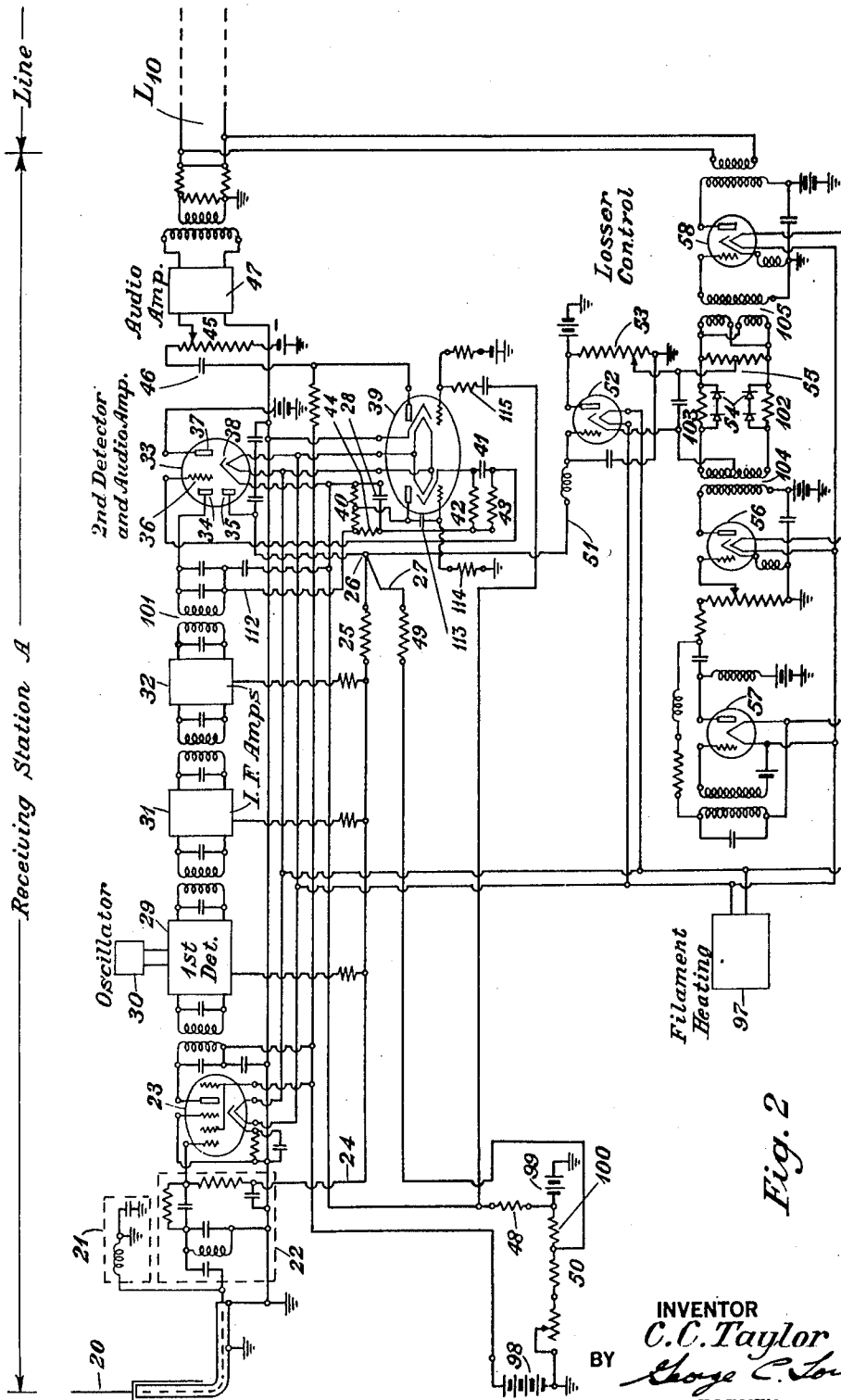


Fig. 2

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3 Sheets-Sheet 3

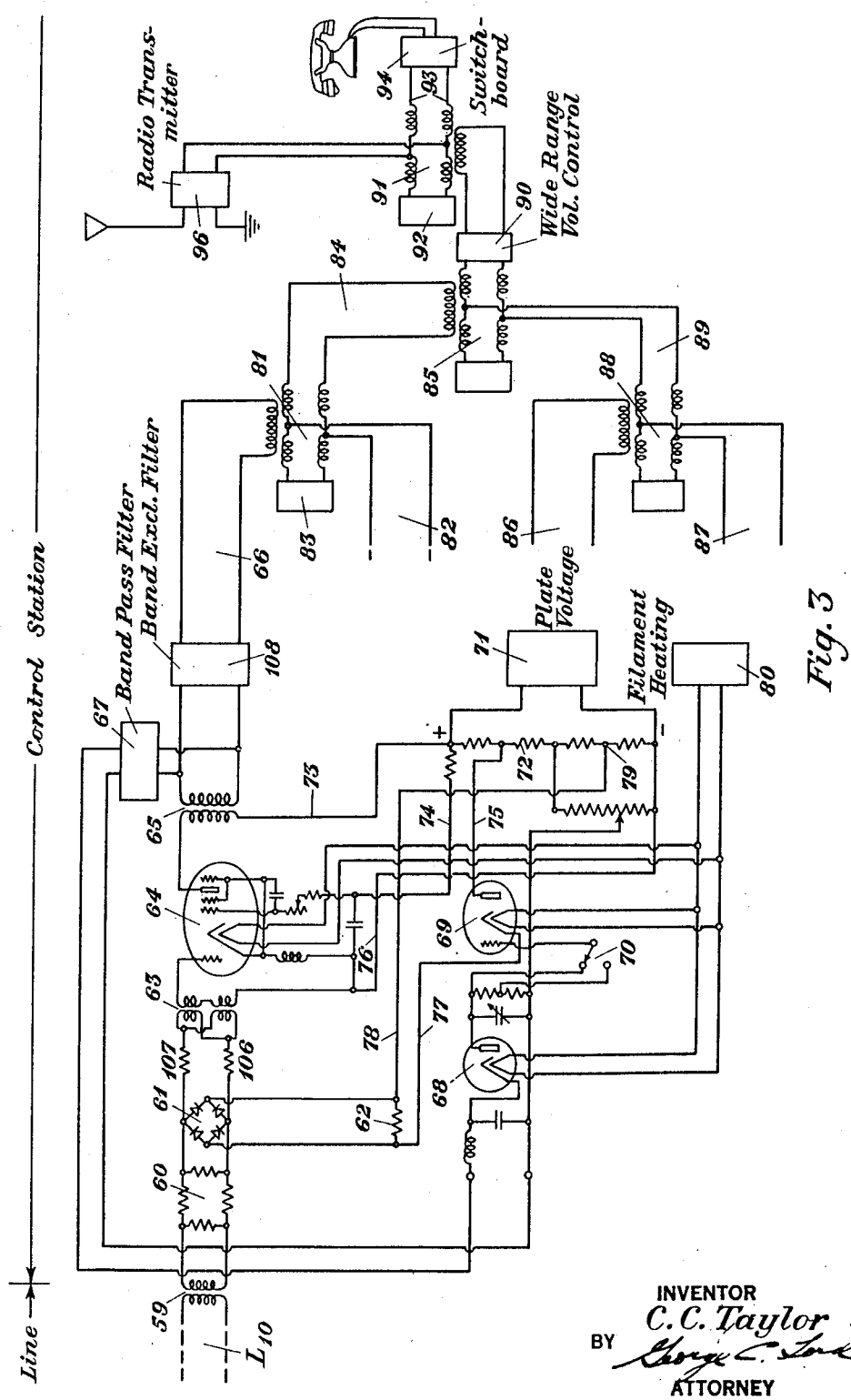


Fig. 3

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UNITED STATES PATENT OFFICE

2,375,051

RADIO RECEIVING SYSTEM

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Application December 7, 1943, Serial No. 513,247

3 Claims. (Cl. 250—20)

This invention relates to a radio telephone system and particularly to one employing a plurality of geographically separated radio receivers for communicating with mobile radio stations, each of which receivers is connected by a separate line to a common operating center from which the traffic is controlled.

In the operation of a system for communicating with mobile radio stations, such as is represented by a harbor radio telephone system or a police car system, it is customary for the operator to monitor the various lines extending from the operating center to the various receivers and to select that line which has the most satisfactory output. Such an arrangement has not proved satisfactory because the operator may not always select the best receiver, or because the mobile unit may move out of the range of one receiver and into that of another without prompt detection by the operator. Various methods have been proposed to avoid the difficulties just stated, such as the provision of automatic selection of the best receiver or the automatic combining of receiver outputs so that no selection is required from the operator.

If the receiver outputs are directly combined the phase difference or differences between the currents arriving at the control center may prove detrimental. Furthermore, where each receiver is provided with automatic volume control the receiver or receivers having the lowest signal strength at any instant may contribute sufficient noise at the control center to considerably impair the signal received from a receiver that is within the closest range to the mobile station. The present invention resides in a method and means by which the receiver that lies in the strongest signal field will automatically contribute the major part of the total signal current that is received at the switchboard at the control center to which all receivers are connected, and in like manner, the receivers in a weak signal field will contribute substantially nothing to the total current strength at the control center.

This invention will be clearly understood from the following description when read in connection with the attached drawings in which:

Fig. 1 shows schematically a system in which the invention is embodied;

Fig. 2 illustrates one of the receiving stations of a system; and

Fig. 3, when arranged with the short lower edge adjacent to the short upper edge of Fig. 2, shows the manner in which the receiver is connected to the control center at which is located

the apparatus by which the discrimination in favor of strong signals and against weak signals is effected.

In Fig. 1, 1 represents a mobile radio station such as a radio car which is equipped to communicate with the radio telephone system shown in Fig. 1. This system comprises a plurality of antennae, such as 2, 2', etc., by means of which the signals sent out by the radio car are received and transmitted to a common control station common to all receivers. Antenna 2 is connected to a radio receiver preferably of the superheterodyne type which is here represented by the radio frequency amplifier and first detector 3, the intermediate frequency amplifiers 4 and the second detector and automatic volume control device 5. The signal resulting from the second detection is applied to the line L₁. The volume control voltage is applied over the circuit 6 to the first detector and also to the intermediate frequency amplifiers in a manner that is well understood, which voltage tends to maintain constant the signal output of the receiver. That signal is transmitted over the line L₁ to the control station and is there combined with the signal picked up by the antenna 2' and transmitted over the line L₂. If the radio car is near the antenna 2 and remote from the antenna 2', the strength of the signal at antenna 2 will be much greater than at antenna 2', the ratio of desired signal to atmospheric noise going over the line L₁ will be much greater than that going over the line L₂, and it would be desirable if the signal received by the operator would be that contributed solely by the line L₁. The strength and usefulness of that signal from L₁ may be impaired by that received from the line L₂ by virtue of phase differences and also owing to the amount of noise that may be transmitted by the line L₂.

In order to discriminate against L₂ and in favor of L₁ certain control apparatus has been added to the circuit, which apparatus is in turn controlled by the strength of the automatic volume control voltage. That apparatus includes an oscillator 7 at the receiving station and a lossy control 8 to which the oscillations are applied, and by means of which the strength of the oscillations of the frequency f₁ may be controlled. Those oscillations of that frequency are applied to the line L₁ together with the signal, and are impressed upon a variolossy 9 at the control center. The control frequency f₁ is selected by the band-pass filter 10 and when rectified by 11 is impressed upon the variolossy 9. By that action the variolossy introduces a minimum loss for

strong signals and a maximum loss for weak signals impressed upon the antenna 2. The signals pass through the filter 12 and are impressed upon the hybrid coil 13 together with signals from the line L_2 . Those combined signals then pass through the volume control 14 to the hybrid coil 15, which serves as the junction between the receiving and the transmitting paths of the control station. The hybrid coil is connected to a switchboard 16. The transmitting path at the control station includes the radio transmitter 17 which is connected to the transmitting antenna 18 by which signals are sent to the mobile radio stations.

The apparatus associated with the other receiving stations and their associated lines is similar to that just described.

Having in mind the description of the foregoing apparatus, the invention will be clearly understood by describing the manner in which a signal is received and transmitted. The signal picked up by the antenna 2 will be impressed upon the amplifier and detector 3, and the resultant intermediate frequency when amplified by 4 will be impressed upon the second detector and the automatic volume control circuit 5. The signal that is detected by 5 will be impressed upon the line L_1 . The automatic volume control voltage which corresponds to the strength of the signal will be impressed by the circuit 6 upon the grids of the detector and amplifiers preceding the second detector, and will tend to maintain constant the signal output of the second detector. That same voltage is also applied to the lossor control and thereby determines the strength of the oscillations of the frequency f_1 which are produced by the oscillator 7 for transmission over the line L_1 to the apparatus at the control center. If the signal is strong the automatic volume control voltage is likewise strong, the gain of the receiver is low, the signal-to-noise ratio high, and the magnitude of the oscillations of the frequency f_1 will be low, and consequently the effect of those oscillations when selected by the filter 10 and rectified by the rectifier 11 will be small when impressed upon the variolossor 9. Accordingly, the signal passing through the variolossor 9 will be substantially unaffected in strength by such control, and will pass through the filter 12 to the hybrid coil 13 where it will be combined with whatever is at that instance coming over the line L_2 . Now assuming that the signal picked up by the antenna 2' is relatively weak so that the gain of the receiver is high and the ratio of the signal to noise is small, the strength of the automatic volume control voltage would likewise be relatively low in strength. The effect of that voltage when applied to the variolossor 8' would be relatively little, and, accordingly, the oscillations generated by the oscillator 7' would be substantially unaffected as they pass through the variolossor on their way to the line L_2 . That relatively strong control current when selected by the filter 10' and rectified by 11' would substantially reduce the strength of the signal passing through the variolossor 9', thereby decreasing the effect of that signal upon the combining network 13. It will accordingly be seen that by means of that control system there is an automatic discrimination in favor of the high signal-to-noise ratio output transmitted to the line L_1 , and discrimination against the low signal-to-noise ratio output transmitted by the line L_2 with the result that the strength and signal-to-noise ratio of the signal passing through the volume control device 14 and through the hybrid coil 15 to the switchboard 16

have substantially the same value as that of the strongest signal picked up by any receiver connected to the said system.

Figs. 2 and 3, when arranged so that the conductors of the line L_2 at the upper edge of Fig. 2 join the corresponding conductors of that line at the lower edge of Fig. 3, show in detail the apparatus necessary for the arrangement shown schematically in Fig. 1. In Fig. 2 the antenna 20, which is of the coaxial type, is connected to the tuned input circuit of the radio frequency amplifier. This includes the antenna tuning 21 and the antenna coupling unit 22, which is connected to the signal grid of the radio frequency amplifier tube 23. That grid is also connected by conductor 24 to resistance 25, which in turn is connected to the junction point 26 by which the negative volume control voltage is applied to the grid of tube 23. The output of the first detector 29, which has associated with it an oscillator 30 by means of which the received signal is converted to an intermediate frequency. The output of the first detector is coupled to the intermediate frequency amplifier 31 which in turn is coupled to a second intermediate frequency amplifier 32.

The output of the second intermediate frequency amplifier 32 is applied through the intermediate frequency filter 101 to the second detector which comprises the diode plate 34 and cathode 38 of the duplex diode-triode tube 33. For the purpose of producing the automatic volume control voltage the direct current component of the output of the second detector 34-38 produced across the detector load resistance 40 is applied through the resistances 44 and 43 in series to the grid 36 of the triode section of tube 33. (This triode section also serves as an audio-frequency amplifier as will be described later). The amplified output of the triode section appears across the load resistance 48. When no signal is being received the voltage across resistance 48 will be a maximum and the automatic volume control diode plate 35 will be negative with respect to the cathode 38 so that no current is passed. However, if a sufficiently strong signal is received the direct current voltage across resistance 48 will decrease sufficiently to permit the plate 35 to become positive with respect to the cathode 38 and current proportional to the potential difference will flow through the load resistance 49. The voltage drop in the resistance 49 is the automatic volume control voltage and is applied to the controlled stages through the filter resistor 25. The current flow through the resistance 49 is established by virtue of the voltage supplied by battery 99, the net voltage between the anode 35 and cathode 38 being determined by the difference between the voltage drop in load resistance 49 and the voltage supplied by the resistance 100 of the voltage divider 50.

The double triode tube 39 operates as a noise gate and as the second audio-amplifier stage. The left-hand section of the tube 39 is the noise gate and for all audio- and radio-frequency voltages operates as a diode by virtue of the condenser 113 which interconnects the plate and grid. The plate is connected to the mid-point of the detector load resistance 40 while the cathode is connected through resistance 42 to the junction of resistance 44 and condenser 28 which are bridged across the load resistance 40. For audio-frequency voltages the grid 36 is connected to this cathode through the condenser 41 and for direct current voltages is connected to the junction

of resistances 44 and 42 through resistance 43.

The voltages on this diode unit (left-hand section of tube 39) are so proportioned that during reception of a carrier the anode is positive with respect to the cathode so that it is conducting and transfers the audio voltage to grid 36. When a high amplitude noise peak of short duration is received, however, the anode momentarily goes negative with respect to the cathode and the audio path to grid 36 is interrupted.

In order to reduce the audio-frequency gain of the receiver when no carrier is being received, use is made of the grid of the left-hand section of tube 39. When no carrier is being received, this grid being connected to ground through resistance 114 is sufficiently negative with respect to its cathode that the audio path is interrupted. However, when a carrier is being received this grid becomes positive, completing the audio path and allowing this section of the tube 39 to act as a diode for noise suppression as described in the paragraph just preceding.

For a more detailed description of the circuit functions just described reference is made to United States Patent 2,208,398 to B. H. Simons, July 16, 1940.

The electrodes at the right-hand side of the tube 39, as shown in the figure, constitute the second audio-frequency amplifier. For this purpose the grid is connected to the load resistance 48 through the resistance-condenser 115. The output is taken from the plate which is coupled by the resistance 45 and the condenser 46 to the input of the audio-frequency amplifier 47, which in turn is coupled to the line L_{10} , which line extends to the control station.

In addition to the variable portion of the volume control voltage appearing across resistance 49 the voltage between point 26 and ground includes the voltage across the left-hand portion of voltage divider 50. This provides the normal minimum bias. In presence of signals the negative voltage at point 26 is increased proportional to the signal strength to reduce the gain of the receiver.

The volume control voltage at the junction point 26 is applied not only to the grids of the tubes of the radio receiver but also is applied by conductor 51 to the grid of the lossier control tube 52. The voltage between the cathode and the plate of that tube is provided by the potentiometer 53, which is so adjusted as to produce a flow of current from the plate to the cathode of tube 52 and thence through the variolossers 54 of the variolosses 55 in the absence of signal. This current is sufficient to cause low resistance of variolosses 54 which shunt resistances 102 and 103 in series with coils 104 and 105 to make up the variolosses 55. Low series resistance gives a low loss. In the presence of signal the grid of tube 52 becomes more negative from the automatic volume control voltage on conductor 51 thereby reducing the plate current, causing the resistance of variolosses 54 to increase and increasing the loss of the variolosses. The variolosses therefore has minimum loss in the absence of signal and increasing loss with signal above a definite value until a maximum loss is reached determined by resistances 102 and 103. The oscillator 57 is coupled to the amplifier 56 and the variolosses is interposed between the amplifier 56 and the amplifier 58. By means of the variations in the loss of the variolosses which are produced by the tube 52 as a result of changes in the volume control voltage applied to the grid of that tube, the am-

plitude of the oscillations produced by oscillator 57 may be controlled prior to their application to the line L_{10} . The line L_{10} connects to a control circuit, Fig. 3, the function of which is to discriminate in favor of strong signals transmitted over the line L_{10} and to discriminate against weak signals so transmitted. This control circuit includes a variolosses made up of transformer 59, network 60, a varistor 61 across the inner corners of which is bridged the resistance 62, resistances 106 to 107, and transformer 63. This input circuit is coupled by transformer 63 to the vacuum tube 64. The output of that tube is coupled by the transformer 65 to the circuit 66 across which is bridged a circuit that includes the band-pass filter 67, which is adjusted to pass the oscillations of the frequency generated by the oscillator 57 at the receiving station A. The oscillations passed by the filter 67 are applied to the rectifier 68, and the rectified voltage is applied to the grid of the tube 69. A switch 70 is provided to enable the selection of the proper voltage to be made. The plate voltages are provided by the source 71, which is connected across the potentiometer 72 in order to provide the voltages of the proper magnitudes to the several tubes. The plate of the tube 64 is connected to the potentiometer by conductor 73, and the screen grid of that tube is connected to the potentiometer by conductor 74. The plate of the tube 69 is connected to the potentiometer by conductor 75. The grid of the tube 64 is connected by conductor 76 to the negative side of the potentiometer. One side of the resistance 62 is connected by conductor 77 to the cathode of the tube 69, and the other side of that resistance is connected by conductor 78 to the point 79 on the potentiometer. The heating elements of the various tubes are supplied by the source 80.

Connected in the circuit 66 is a band exclusion filter 108 which excludes the control frequency generated by oscillator 57 but permits the passage of the audio signal frequencies which are applied to the line L_{10} by the radio receiver. Those signal frequencies are applied to the combining network, that is, the hybrid coil 81 to which is also connected the circuit 82 which represents another input circuit similar to circuit 66 and connected to a receiving system similar to that just described. The hybrid coil 81 has connected to it a balancing network 83 which balances the line 84 that extends to another hybrid coil 85. Other input circuits, such as 86 and 87 which are also connected to receiving systems similar to that described are connected by the hybrid coil 88 in order to combine their signals, and the combined output is impressed by the circuit 89 upon the hybrid coil 85 together with the input of the circuit 84. The resultant current of all those combining operations is impressed upon the wide range volume control device 90, and the output of that is impressed upon the hybrid coil 91, which is connected between the balancing network 92 and the line 93 that extends to the switchboard 94. The circuit 93 is a two-way circuit in that it transmits not only the received signals to the switchboard but also the transmitted signals which are impressed upon the branch 95 and applied to the radio transmitter 96.

The manner in which this system functions in order to attain the objective of this invention is as follows: Let it be assumed that no signal is being received by the antenna 20. The tubes would, of course, be activated by the heat-

ing currents supplied by the source 97 and by the plate voltages supplied by the source 98 and the other sources shown on the drawings. It should, of course, be understood that it is common practice to supply those voltages from a common source, but in order to simplify the connections of the drawings, separate sources of plate voltage are shown. As previously described when no signal is being received, the plate 35 of the diode 35-38 is negative with respect to its cathode, and no current flows through resistor 49. Under that condition the voltage applied by conductor 51 to the grid of the control tube 52 has a minimum negative value, establishing the condition of maximum space current of that tube. That space current flowing through the varistors 54 of the device 55 lowers the series resistance of that device and permits oscillations of the maximum amplitude to pass from the oscillator 57 to the line L₁₀. Those oscillations will be impressed upon the tube 64, and after selection by the filter 67 will be impressed upon the rectifier 68. Since that control current is strong, the shunting effect of the varistor 61 while be great thereby introducing loss into the variolossor and tending to diminish any weak signals.

Now let it be assumed that a strong signal is being received by the antenna 20. Under such conditions there will be developed across the resistance 49 a voltage making point 26 more negative with respect to ground as previously described. This voltage is supplied through the filter resistance 25 to the grids of the radio frequency amplifier 23, the first detector 29 and the intermediate frequency amplifiers 31 and 32 to cause the automatic volume control action.

The negative voltage at point 26 derived from the current in resistance 49 is also applied to the grid of the tube 52, thereby diminishing the space current of that tube. Since that space current flows through the varistors 54, the resistances of this device is increased, and consequently the amplitude of the oscillations produced by 57 are reduced as they pass through the variolossor 55. Accordingly for a strong signal coming from the antenna 20, the amplitude of the control oscillations that is impressed by the amplifier 58 upon the line L₁₀ is diminished. Those oscillations of diminished amplitude but of the frequency of the device 57 will pass to the control circuit at the station B, and after passing through the amplifier 64 will be selected by the filter 67 and impressed upon the rectifier 68. Under the assumed condition of a smaller amplitude of the control oscillations the voltage applied to the grid of the tube 69 will be less and the space current of that tube, which is the current that flows through the resistance 62, will likewise be small. Accordingly the current that flows through the varistor 61 will be smaller than under the condition first assumed, and consequently the shunting effect of the varistor 61 upon the signal received by the antenna 20 and ultimately impressed by the line L₁₀ upon the control circuit will be less. Accordingly that signal will pass to the amplifier 64, with less loss, and thereafter will pass through the filter 108 to the circuit 84, wherein it will be combined with any signal that may be coming in over the circuit 82. That combination of signals will be impressed upon the hybrid coil 85 together with the combination of signals received by circuits 86 and 87, and the resultant of all those, after being adjusted as to volume by the device 90, will be impressed by the hybrid coil 91

upon the circuit 93 for transmission to the switchboard 94.

As mentioned hereinbefore, the circuits 82, 86 and 87 are connected through a control station, a line and a receiving station to an antenna, all of which are similar to those shown in connection with the circuit 66. With such an arrangement if the signal received by the antenna 20 transmitted over the line 10 to the circuit 66 is a strong signal the control oscillations generated by the oscillator 57 and applied to the line L₁₀ in accordance with the control effected by the devices 52-55 will be such as to insure the transmission of the incoming signal without impairment of its strength. On the other hand, if the signals received by the antennae connected with the radio receivers that form part of the circuits connected to the lines 82, 86 and 87 are weak signals, the control oscillations set up by oscillations similar to 57 will control varistors similar to 61 in each of the other control circuits in such manner as to reduce the strength of the signals received by the said other antennae and to reduce the strength of noise that may be picked up by the said other antennae or that might arise within the circuits themselves. In that fashion the strong signal coming from the antennae which lie in the field of greatest strength will contribute all or substantially all of the signal that reaches the control switchboard 94. The weaker signals will in a converse manner be prevented from contributing to any substantial degree toward the effect at the control switchboard, thereby reducing interference with the strong signal from the desired station.

It is desirable to point out that, in setting up a system such as that hereinbefore described, the time actions of the automatic volume control, the variolossor and the wide range volume control must be carefully coordinated. It is necessary that the voice output from each receiver line be properly poled or phased with respect to that from all other receiver lines. For relatively short receiver lines there is no problem of delay, but if the lines are of appreciable length, delay equalization will be required.

While this invention has been disclosed as embodied in a particular form and arrangement of parts, it is capable of embodiment in other and different forms without departing from the spirit and scope of the appended claims.

What is claimed is:

1. A radio receiving system comprising a plurality of radio receivers at different geographical locations and all adapted to receive the same signal, an automatic volume control circuit for each of said receivers including means for producing a voltage directly proportional to the received field strength, a central station, a signal circuit connecting the signal output of each of said receivers to said central station, a common output circuit at said central station for all of said signal circuits, a variolossor in each of said signal circuits at said central station, and means responsive to each of said voltages directly proportional to the received field strengths for regulating the corresponding one of said variolossors whereby the loss introduced into each circuit is inversely proportional to the received field strength at the corresponding receiver.

2. A radio receiving system comprising a plurality of radio receivers at different geographical locations and all adapted to receive the same signal, an automatic volume control circuit for each of said receivers, means for producing a pilot

voltage proportional to the received field strength at each of said receivers, a central station, a transmission circuit connecting each of said receivers to said central station and adapted to transmit both the signal output and the pilot voltage, a common signal output at said central station for all of said transmission circuits, and means at said central station in each of said transmission circuits for regulating the gain thereof in accordance with the corresponding pilot voltage.

3. A radio receiving system in accordance with claim 2 in which the automatic volume control circuit for each receiver includes means for producing a voltage directly proportional to the received field strength and each means for producing a pilot voltage includes an oscillation generator, and means for controlling the amplitude of the oscillatory voltage output in accordance with said voltage directly proportional to the received field strength.

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