

Dec. 6, 1949

E. A. JENSEN ET AL

2,490,061

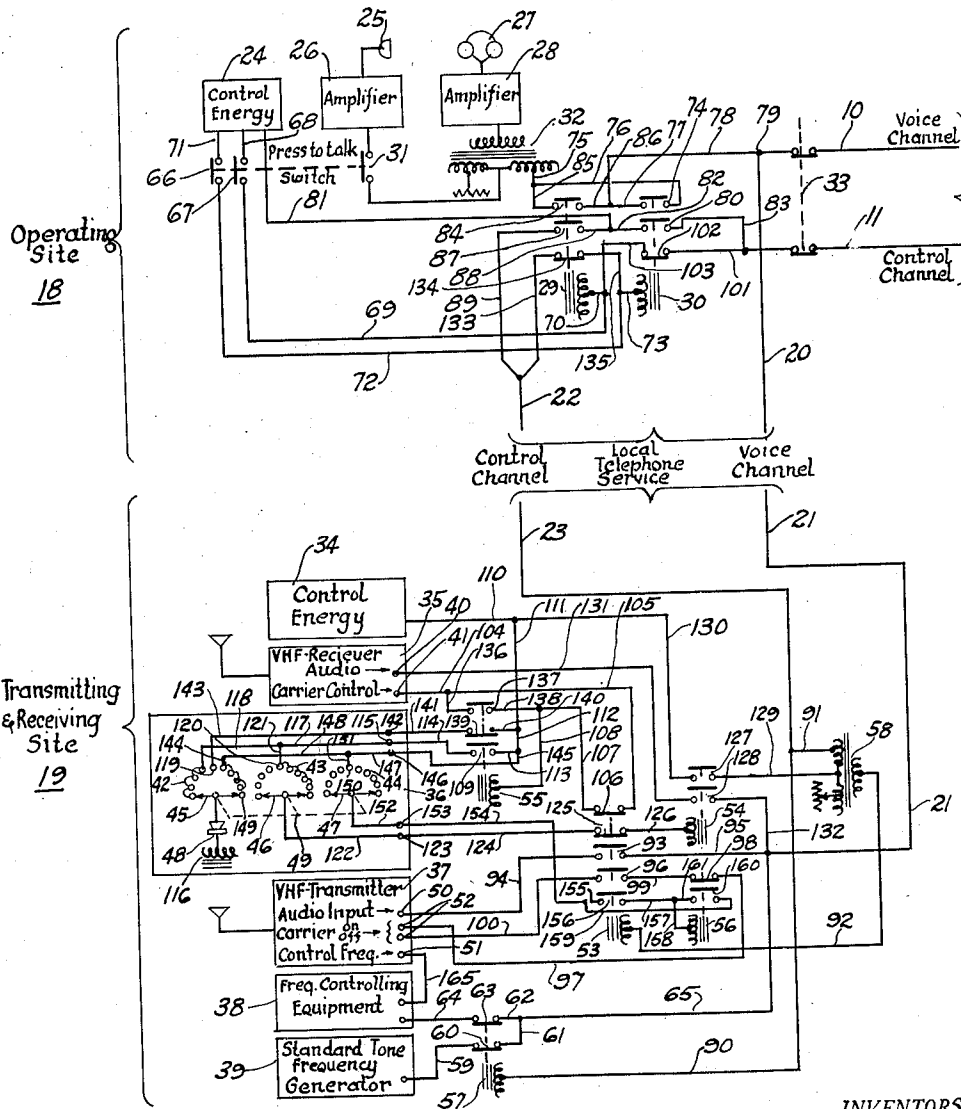
RADIO-WIRE COMMUNICATION SYSTEM

Filed July 31, 1947

5 Sheets-Sheet 1

Fig. 1a

STATION NO. 1



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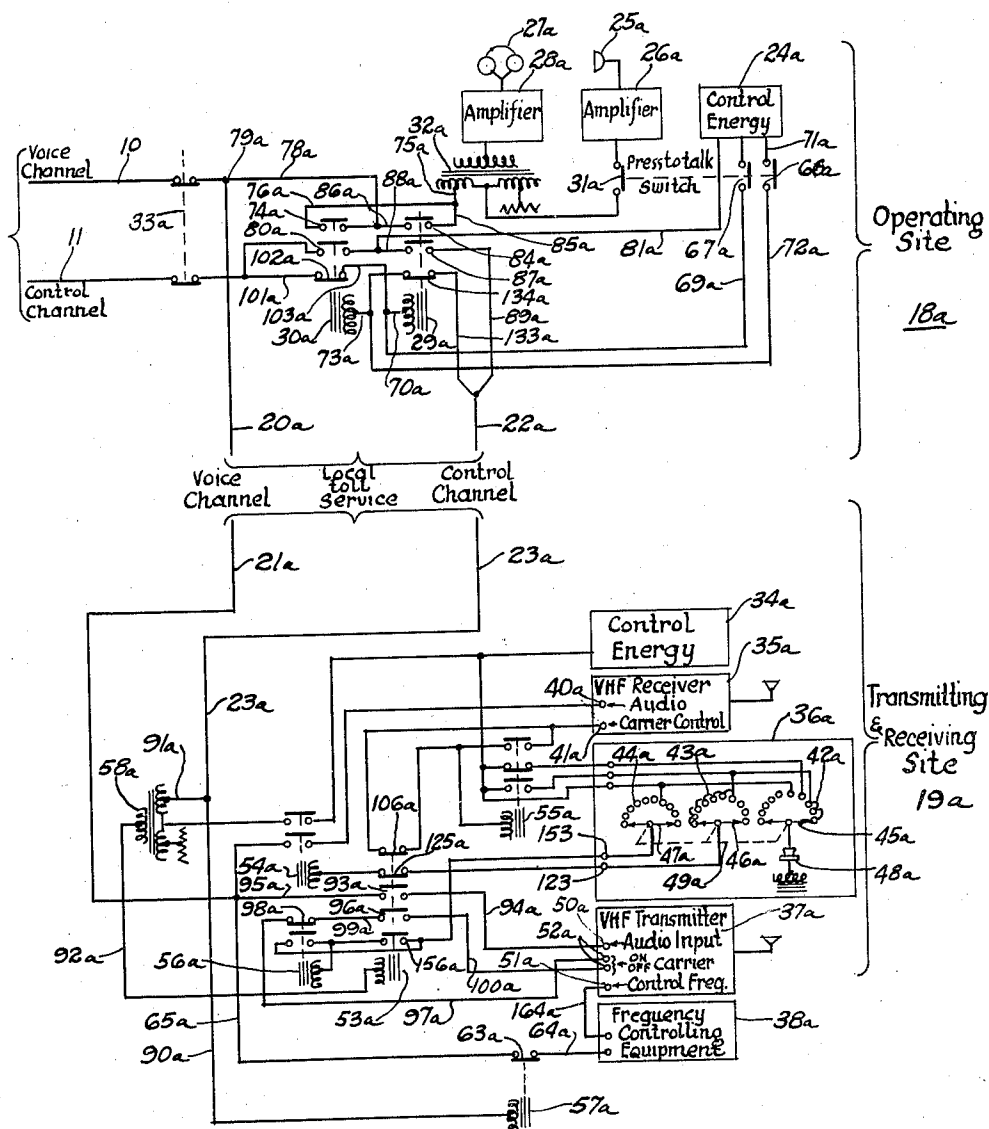
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5 Sheets-Sheet 2

Fig. 1b

STATION NO. 2



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RADIO-WIRE COMMUNICATION SYSTEM

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5 Sheets-Sheet 3

Fig. 2

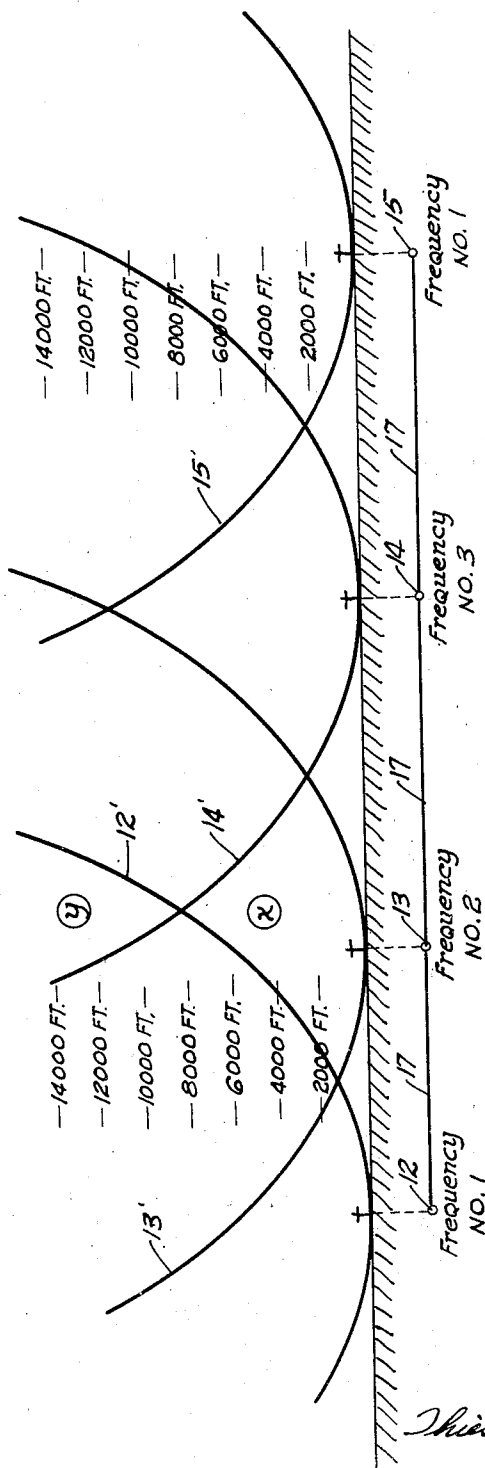
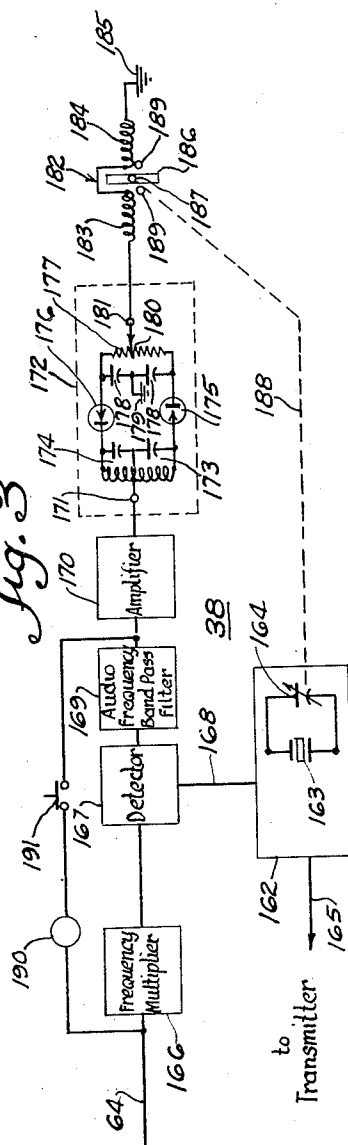


Fig. 3



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RADIO-WIRE COMMUNICATION SYSTEM

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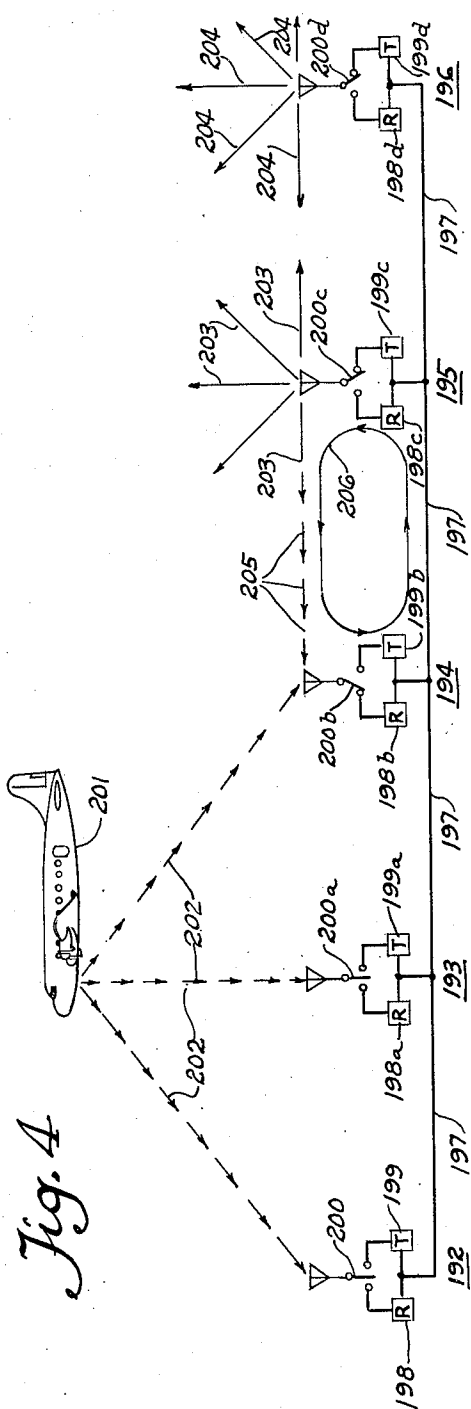


Fig. 4

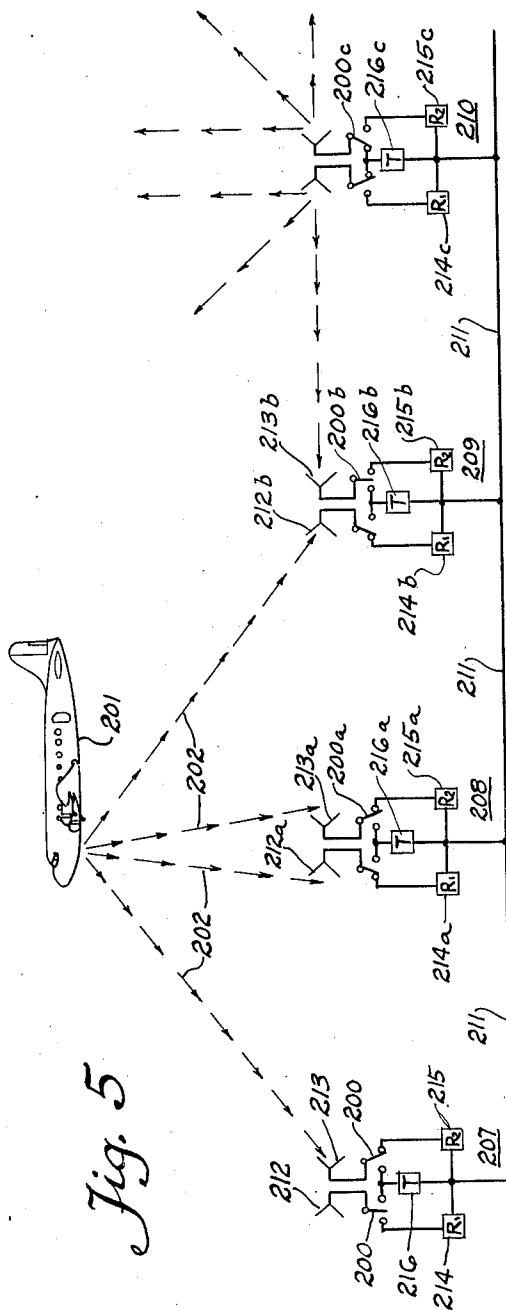


Fig. 5

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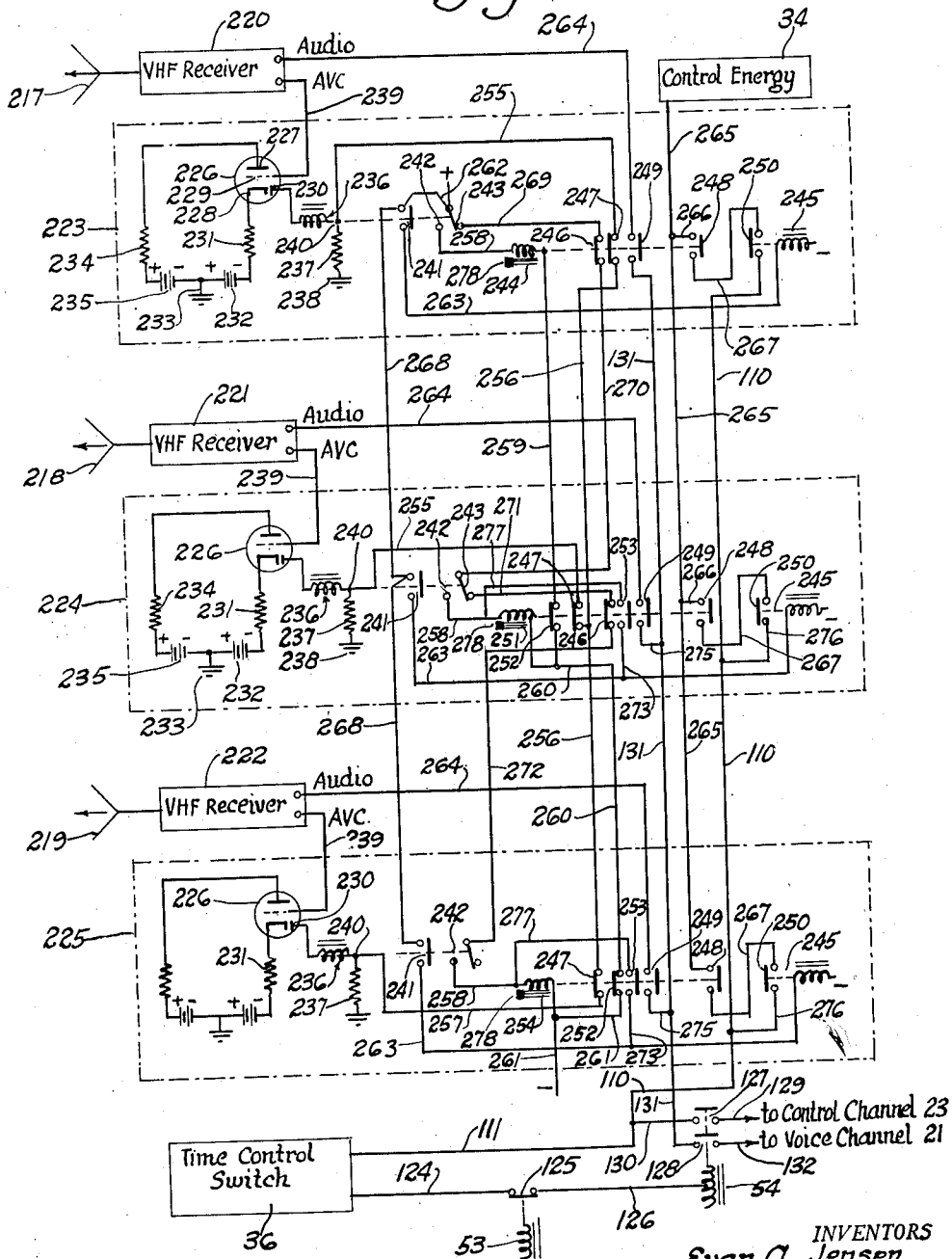
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RADIO-WIRE COMMUNICATION SYSTEM

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5 Sheets-Sheet 5

Fig. 6



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UNITED STATES PATENT OFFICE

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RADIO-WIRE COMMUNICATION SYSTEM

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Application July 31, 1947, Serial No. 764,994

26 Claims. (Cl. 250-6)

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This invention relates to radio communication systems for aircraft; more particularly, to systems for effecting two-way radio communication between aircraft, and between aircraft and ground, over distances in excess of the normal range of transmission and reception at the operating frequencies; and the invention has for an object the provision of economical and reliable systems of this character.

Communication systems of the type indicated, operating on a single channel or assigned frequency, should, in order to achieve maximum utility, be so constructed and arranged that any ground station may communicate with any aircraft operating over the system, that any aircraft may communicate with any ground station in the system over which it is operating, that all ground stations may communicate with each other, that all aircraft and all ground stations may know when the system is in use so that interference will not be had, and that all aircraft operating over the system may hear all communications whether from ground stations or other aircraft so as to be continuously advised of operating conditions throughout the entire system. At present all of these requirements are being met by aeronautical communication systems employing long-distance high-frequency radio equipment.

With the development of VHF equipment, i. e., equipment capable of operating at very high frequencies, such for example as 100 megacycles, it has become desirable for various reasons to employ these very high frequencies in aeronautical communication systems. Radio equipment operating at such very high frequencies, however, has a very limited range, and consequently to satisfy the above requirements it is necessary to employ a plurality of spaced ground stations interconnected by suitable wire circuits, such as telephone or Teletype circuits.

Perhaps the simplest arrangement that could be employed for such purposes, at least from the equipment standpoint, is to have each station individually controlled by its individual operating staff, who would relay messages by telephone or teletype to all of the other ground stations. With this arrangement many of the messages between ground and air would be secondhand, message transmission would be comparatively slow, and the operating personnel would necessarily be maintained on a 24-hour basis. A second arrangement, which would readily occur to those skilled in the art, would be to provide selective equipment enabling the operator at any control

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station to select one or more transmitting stations in the system and operate the transmitters at those stations. For example, a Chicago operator desiring to communicate with an aircraft over Des Moines, could, by suitable wire circuits, select the Des Moines transmitter and communicate directly with the desired aircraft. One of the principal disadvantages of a selective system of this kind is that the operator must know the location of the aircraft in order to select the proper transmitter. Furthermore, interference between messages would inevitably occur whenever two or more aircraft operating out of range of each other, and therefore unadvised as to the activities of the other, should attempt to communicate with a ground station at the same time. Having in mind the above requirements, it is a further object of this invention to provide a system for effecting two-way radio communication between aircraft and ground which will meet all of the requirements of maximum utility, which requires a minimum of operating personnel, and which permits direct communication with all aircraft operating over the system either from other aircraft or from ground, and with all ground stations in the system either from other ground stations or from aircraft operating over the system.

It is another object of this invention to provide a system of the above character wherein a message originating at any ground station is reproduced and rebroadcast at each ground station in the system.

Another object of the invention is the provision of a system of this character wherein an aircraft-initiated message when received at any one station is reproduced at all of the stations in the system but is rebroadcast only from ground stations outside of the range of the initiating aircraft.

Still another object of this invention is the provision of a system of this character wherein only one receiving station operates to distribute an aircraft-initiated message throughout the system for reproduction and rebroadcast even though the message is received at more than one ground station.

A further object of the invention is to provide a system of this character wherein the possibility of interference, by reason of the reception of a message at an aircraft from more than one ground transmitter, is prevented by dividing the receiver band-pass acceptance channel at the assigned frequency into a plurality of subchannels and energizing adjacent transmitters in the system

at closely controlled different subchannel frequencies to provide a resultant heterodyne beat note of a frequency high enough to be readily filtered-out at the aircraft receivers.

In carrying out the invention in one form, a plurality of ground stations are provided, spaced apart distances greater than the normal transmitting and receiving range at ground level, but close enough to provide overlapping zones of ground transmitted signals at the usual aircraft altitudes, and close enough to permit simultaneous reception at a plurality of ground stations of aircraft signals transmitted at such altitudes, and means are provided extending between the ground stations and forming voice and control energy channels, together with means automatically responsive to the initiation of a message at any one of the ground stations for reproducing and broadcasting the message at each ground station, and means automatically responsive to the reception of an aircraft-initiated message at any one of the ground stations for reproducing the message at all of the stations and for rebroadcasting the message only from ground stations outside of the range of the message-initiating aircraft. In addition, timing means may be provided at each station having different time settings at adjacent stations whereby in the event of simultaneous reception of a message at more than one station, all but one of the receivers will be disabled so that audio and control energy will be supplied to the voice and control channels of the system from only one of the receiving stations, the timing means in addition being arranged to disable the transmitter at each of the stations wherein the message is being received even though the receiver at that station is disabled.

In accordance with another aspect of the invention, the transmitters at adjacent stations are operated at different subchannel frequencies within the band-pass channel of the aircraft receivers, and frequency control means are provided at each station for holding the transmitter closely on the subchannel frequency, the frequency control means being energized, during intervals when no message is being transmitted, by a common standard-frequency tone transmitted to all of the ground stations over the voice channels and adapted to be automatically removed from the voice channels whenever a message is initiated.

For a more complete understanding of the invention, reference should now be had to the drawings, in which:

Figs. 1a and 1b, when placed side by side, with the right-hand side of Fig. 1a adjacent the left-hand side of Fig. 1b, illustrate diagrammatically a communication system embodying the present invention;

Fig. 2 is an explanatory diagram illustrating the manner in which a plurality of ground stations may be spaced apart and interconnected to provide overlapping signal zones at various aircraft altitudes;

Fig. 3 is a circuit diagram illustrating the frequency control means employed at each of the ground stations of the system illustrated in Figs. 1a and 1b;

Figs. 4 and 5 are explanatory diagrams illustrating certain operating conditions that may be encountered with systems embodying the present invention; and

Fig. 6 is a circuit diagram showing automatic control means for insuring the achievement of

the operating condition shown in Fig. 5 and preventing the disadvantageous condition illustrated in Fig. 4.

Referring now to the drawings, the invention is shown as embodied in a communication system comprising two ground stations, respectively identified as "Station No. 1" (Fig. 1a) and "Station No. 2" (Fig. 1b). In order to simplify the drawing, single lines have been employed throughout to illustrate the various circuits, but it will be understood that each circuit includes the usual return circuits and ground connections. For convenience the single lines employed in the drawing will be referred to throughout as "conductors," but it will be understood that each single line may constitute more than one conductor and such additional circuit elements as may be necessary in each instance in accordance with standard practice. Stations No. 1 and No. 2, as will be more fully explained hereinafter, are connected by suitable long-distance telephone lines, exemplified in the drawings by a voice channel 10 capable of high-speed transmission of audio-frequencies, and by a control channel 11 which may constitute any type of circuit capable of transmitting control energy; and it will be understood that the two stations illustrated are merely exemplary of a larger number of identical stations all of which are connected to the long-distance voice and control channels. For example, in Fig. 2 a system embodying the invention is diagrammatically indicated as comprising ground stations 12, 13, 14, and 15 connected by suitable long-distance telephone lines 17. While a separate control channel is employed in the embodiment of the invention shown, it will be understood that the same circuits that comprise the voice channel may be employed for transmitting suitable control signals, thus eliminating the necessity for a physically separate control channel.

Referring now specifically to Fig. 1a, Station No. 1 of the system is shown as comprising an operating site 18 and a transmitting and receiving site 19, which are in the usual case located at some distance from each other and are therefore connected by local voice and control energy channels, respectively represented in Fig. 1a by the conductors 20, 21, and 22, 23. It may be desirable in some installations to connect more than one operating site to a single transmitting and receiving site, and this may readily be accomplished through local telephone service circuits, as indicated by appropriate legends on the drawing.

As shown, the operating site 18 comprises a source of control energy 24, a sound pickup device, which is illustrated as comprising a microphone 25 connected to a suitable constant level amplifier 26, a sound reproducing device, which is illustrated as comprising a headphone set 27 connected to a suitable amplifier 28, and a pair of automatic switching devices or relays 29 and 30 for selectively connecting the sound pickup and sound reproducing devices to the voice channels and connecting the source of control energy to the control channels, as will be more fully explained hereinafter.

As shown, the output circuit of the microphone amplifier 26 and the input circuit of the headset amplifier 28 are interconnected in the usual manner through a manually operable press-to-talk switch 31 and a conventional hybrid coil 32, which latter is employed for anti-side-tone purposes and is adapted to be connected to the voice channels through the contacts of the relays 29 and 30. In

addition, a suitable manually operable switch 33 may be provided, as shown, for isolating the station from the long-distance voice and control channels if desired. The various devices going to make up the operating site of the ground station and the interrelation therebetween will be more fully explained hereinafter in the description of the operation of the system.

The transmitting and receiving site 19 includes a source of control energy 34, a conventional VHF receiver 35, a time control switch or timing device 36, a conventional VHF transmitter 37, a frequency controlling device 38 for supplying a controlled frequency to the transmitter, and a frequency generator 39 for producing a standard-frequency tone the purpose of which will be more fully set forth hereinafter. As previously indicated, the VHF receiver 35 is of conventional construction and includes an audio-output circuit, represented by the terminal 40, and a carrier control circuit, represented by the terminal 41, the carrier control circuit, as will be understood by those skilled in the art, being energized only when a carrier of the proper frequency is being received.

The time control switch 36 may be of any desired type available on the market, and is shown for purposes of illustration as comprising a stepping switch having three banks of contacts 42, 43, and 44 adapted to be sequentially engaged by movable contact arms 45, 46, and 47, respectively, when the switch is energized with pulses obtained from an alternating current source through a half-wave rectifier 48. Time control switches of this general character are well known in the art, and accordingly it is not believed necessary to illustrate the actual operating mechanism employed other than to indicate by the broken lines 49 that the three contact arms 45, 46, and 47 are connected together for simultaneous operation. It will be understood that other types of timing devices or circuits may be employed, if desired, in place of the time control switch 36.

The VHF transmitter 37 is of the type including an audio-input circuit 50, a control frequency input circuit 51 adapted to be energized from the usual crystal-controlled oscillator to produce the desired carrier frequency, and a carrier control circuit represented by the terminals 52, which circuit when opened and closed is effective to turn the transmitter on and off, i. e., to initiate and terminate the transmission of a message. In addition, the transmitting and receiving site 19 includes a number of automatic switching devices or relays 53, 54, 55, 56, and 57 for controlling the receiver and transmitter and the various devices associated therewith. Finally, the site 19 includes a suitable hybrid coil 58 the purpose and operation of which will be explained hereinafter.

Referring now to Fig. 1b, the equipment included in both the operating site and the transmitting and receiving site of Station No. 2 is, with minor exceptions, identical with the equipment at Station No. 1. Accordingly the same reference numerals with the suffix "a" added thereto will be used to identify corresponding equipment and components. The exceptions to the identity are that Station No. 2 does not include a standard frequency generator such as the generator 39 at Station No. 1, and consequently the relay 57a at Station No. 2 requires only one pair of contacts instead of the two pairs of contacts required by relay 57 at Station No. 1.

The general nature and the arrangement of some of the principal components of the system

having now been described, it is thought that an understanding of the invention may best be had from a detailed description of the operation of the system during the transmission and reception of both ground-initiated and aircraft-initiated signals. In Figs. 1a and 1b of the drawing the system is illustrated with the various components in the respective conditions corresponding to an interval during which no signal is being either transmitted or received. During such an interval the frequency generator 39, for supplying a standard tone to the frequency controlling equipment at the various ground stations, is connected through the conductor 59, the contacts 60 of the relay 57, conductors 61 and 62, the contacts 63 of the relay 57, and a conductor 64 to the frequency controlling equipment 38 which, as heretofore indicated, functions to supply a closely controlled frequency to the transmitter 37 in a manner which will be more fully described hereinafter. Likewise the frequency generator 39 supplies a standard tone to the frequency controlling equipment 38a at Station No. 2 by way of a circuit which may be traced through the conductor 59, the contacts 60, and the conductors 61 and 65 to the local voice channel 21 at the transmitting and receiving site 19, thence through the voice channel 20 at the operating site 18, and by way of the upper pair of contacts on the switch 33 to the long-distance voice channel 10. At Station No. 2 the circuit extends from the voice channel 10 through the upper contacts on the switch 33a, and thence through the local voice channel 20a and 21a, a conductor 65a, contacts 63a on the relay 57a, and the conductor 64a to the frequency controlling equipment 38a. Thus during the time intervals when the system is not in use for the transmission or reception of messages, a standard tone produced by the frequency generator 39 will be supplied to the frequency controlling equipment at the various stations.

Assuming that the operator at the operating site 18 at Station No. 1 desires to transmit a message, the first step is to operate the press-to-talk switch 31, thereby to connect the amplifier 26 of the microphone 25 to the middle tap of the hybrid coil 32. The press-to-talk switch 31 includes additional contacts 66 and 67 which, upon closure, effect energization of the relays 29 and 30, respectively, these energizing circuits extending from the source of control energy 24 through a conductor 68, the contacts 67, and conductors 69 and 70 to the operating winding of the relay 29, and from the source of control energy 24 through a conductor 71, the contacts 66 and conductors 72 and 73 to the operating winding of the relay 30. Operation of the relay 30 effects, through closure of its contacts 74, connection of the microphone 25 to both the long-distance voice channel 10 and local voice channel 20, the circuit being traceable from the right-hand terminal of the hybrid coil 32 through conductors 75 and 76, the contacts 74, and by way of conductors 77 and 78 to the common terminal 79 to which both of the voice channels are connected. Simultaneously closure of the contacts 80 on the relay 30 effects connection of the source of control energy 24 to the long-distance control channel 11, through a circuit which extends from the source 24 through conductors 81 and 82, the contacts 80, and a conductor 83 to the control channel 11.

Similarly, operation of the relay 29 is effective, through closure of its contacts 84, to complete a circuit which includes the conductors 85 and 86,

and which is in parallel relation to the circuit including the contacts 74 of the relay 30 through which the hybrid coil 32 is connected to both the long-distance and local voice channels, these parallel circuits insuring connection of the microphone 25 and the headset 27 to the voice channels upon operation of either of the relays 29 or 39. Finally, operation of the relay 29 is effective, through closure of its contacts 87, to connect the source of control energy 24 to the local control channel 22, 23, the circuit being traceable from the source 24 through conductor 81, a conductor 88, the contacts 87, and the conductor 89 to the control channel 22.

Connection of the microphone 25 to both the long-distance and local voice channels, and connection of the source of control energy 24 to both the local and long-distance control channels are effective, as will now be described, first to disconnect the frequency generator 39 and all of the frequency controlling equipment from the voice channels; second, to connect the microphone 25 to the headset 28a; third, to connect the microphone 25 to the audio-input of all of the transmitters; and fourth, to turn on the transmitters so that the message originating at the microphone 25 will be broadcast from all of the ground stations in the system.

Referring first to Station No. 1, it will be seen that as soon as the local control channel 23 is energized, the relay 57 will be operated, the coil of the relay being connected to the control channel 23 through a conductor 90. Thus the contacts 69 are opened to disconnect the frequency generator 39, and the contacts 63 are opened to disconnect the frequency control equipment 38 from the voice channel 21. Simultaneously with operation of the relay 57, the relay 53 is operated, the energizing circuit for relay 53 being traceable from the control channel 23 through a conductor 91, the upper portion of the hybrid coil 58, and a conductor 92 to the operating coil of the relay 53. Upon operation of the relay 53, the contacts 93 thereof close to connect the audio-input 59 of the transmitter to the voice channel 21 through a conductor 94, the contacts 93, and a conductor 95. Likewise, closure of the contacts 96 on the relay 53 completes a circuit between the carrier control terminals 52 of the transmitter; which circuit may be traced from the upper one of the terminals through a conductor 97, a pair of normally closed contacts 98 on the relay 56, the conductor 99, the contacts 96 on the relay 53, and a conductor 100 to the lower one of the terminals 52. Closure of this circuit turns on the transmitter so that the message originating at the microphone 25 will be broadcast by the transmitter 37.

Referring now to Station No. 2, energization of the long-distance control channel 11, as hereinbefore explained, is effective to cause operation of the relay 29a, the energizing circuit extending from the control channel 11 through a conductor 101a, a pair of normally closed contacts 102a on the relay 28a, and conductors 103a and 104a to the operating winding of the relay 29a. Operation of the relay 29a is effective, through closure of its contacts 84a, to connect the headset 27a to the voice channel 10 by way of a circuit which extends from the voice channel terminal 79a through conductors 78a and 80a, contacts 84a, and conductors 85a and 75a to the end terminal of the hybrid coil 32a to which the headset amplifier 28a is connected. Likewise, relay 29a is effective,

through closure of its contacts 87a, to energize the local control channel 22a, 23a at Station No. 2 from the local source of control energy 24a, this circuit being traceable from the source of energy 24a through the conductors 81a and 88a, the contacts 87a, and the conductor 89a to the control channel 22a. Energization of the control channel 23a at the transmitting and receiving site 19a of Station No. 2 effects operation of the relay 57a to disconnect the frequency control equipment 38a from the local voice channel, the operating winding of the relay 57a being connected through conductor 90a to the control channel 23a. Likewise the relay 53a will be energized through a circuit extending from the control channel 23a, a conductor 91a, the upper half of the hybrid coil 58a and conductor 92a which leads to the operating winding of the relay 53a. As previously described in connection with Station No. 1, operation of the relay 53a is effective, through the closure of its contacts 93a and 96a, to connect the audio-input of the transmitter to the voice channel and to turn on the transmitter, the circuits being identical with those previously traced in the description of Station No. 1.

From the above description it will be apparent that whenever the press-to-talk switch is operated at Station No. 1, the frequency generator 39 will be automatically disconnected from the voice channels, and a message originating at microphone 25 will be broadcast from each of the ground stations. Upon release of the press-to-talk switch, the relays 29 and 39 at Station No. 1 will immediately be de-energized to disconnect both the microphone 25 and the control energy source 24 from the local and long-distance voice and control channels, whereupon the relays 53 and 57 will be de-energized to turn off the transmitter and reconnect the frequency controlling equipment 38 and the frequency generator 39 to the voice channels. Likewise the relay 29a at Station No. 2 will be de-energized to disconnect the source of control energy 24a from the local control channel 22a, 23a, and the relays 53a and 57a will be de-energized to turn off the transmitter 37a and to reconnect the frequency controlling equipment 38a to the voice channels.

The operation of the system to effect broadcasting from all of the transmitters of a message originating at Station No. 2 upon operation of the press-to-talk switch 31a will be apparent from the operation heretofore described, the circuits being identical and interchangeable at both stations. Accordingly the various circuits involved for insuring broadcasting of the message originating at Station No. 2 will not be described in detail. Thus, whenever a message is initiated at any one of the ground stations, that message will be reproduced at each of the other ground stations and will be transmitted from all the transmitters in the system so as to reach any aircraft operating over the system even though the aircraft is completely outside of the range of the initiating station.

It will now be assumed that with the equipment in the normal position illustrated in the drawing, an aircraft-initiated message is received at the receiver 35 of Station No. 1. As soon as this message reaches the receiver 35, the carrier control equipment of the receiver will supply energy from the terminal 41 through conductors 104 and 105, the normally closed contacts 106 of the relay 53, and by way of conductors 107

and 108 to the energizing winding of the relay 55, and the consequent operation of the relay 55 is effective, through closure of its contacts 109, to supply energy from the control energy source 34 to the time control switch 36 through conductors 110, 111, 112, and 113, the contacts 109, and a conductor 114 to one terminal 115 of the time control switch. The source of control energy 34, as well as all of the other heretofore referred-to control energy sources, is preferably a standard 60-cycle source of alternating current, but it will be understood that other frequencies may be used, or if a different type of time control switch or timing device is provided, direct current may be employed.

In the arrangement shown, it will be assumed that the source of energy is 60-cycle alternating current, and upon connection of the terminal 15 to the source 34, the time control switch 36 will begin its stepping operation due to the fact that pulses of energy will be supplied to the operating winding 116 of the switch through a circuit which extends from the terminal 115 through conductors 117 and 118, the four contacts at the left of the contact bank 42, the contact arm 45, and the rectifier 48. The operating mechanism of the time control switch is such that each pulse of energy will cause the switch to move one step, that is, from one contact to the next at each pulse, and consequently the switch 36 will operate through four steps until the contact arm 45 engages the contact 119 of the bank 42, thus interrupting the previously traced energizing circuit. Simultaneously with the engagement of the contact arm 45 and the contact 119, the contact arm 46 on the bank 43 will engage contact 120 of this bank to complete an energizing circuit for the relay 54, which energizing circuit may be traced from the previously energized conductor 117 through a conductor 121, the contact 120, the contact arm 48, the conductor 122, terminal 123, conductor 124, the normally closed contacts 125 on the relay 53 and by way of a conductor 126 to the operating winding of the relay 54.

Operation of the relay 54 is effective through closure of its contacts 127 and 128 to connect the source of control energy 34 to the control channel 23 and to connect the audio-output of the receiver 35 to the local voice channel 21. The control circuit thus completed extends from the source of energy 34 through the conductors 110 and 130, the contacts 127, a conductor 129, the upper portion of the hybrid coil 58, and conductor 91 to the control channel 23. It will be observed that the conductor 129 in this circuit is connected to the center terminal of the hybrid coil 58, and accordingly control energy, while passing through the upper portion of the hybrid coil to the conductor 91, will not pass through the hybrid coil to the conductor 92, whereby the relay 53 remains de-energized and consequently the transmitter 37 at Station No. 1 will not be turned on. Energization of the control channel 23, however, is effective, through the conductor 90, immediately to energize the relay 57 so as to disconnect the frequency generator 39 and the frequency control equipment 38 from the voice channel 21. The circuit for the audio-output of the receiver may be traced from the terminal 40 of the receiver 35 through a conductor 131, the contacts 123 on the relay 54, and by way of a conductor 132 to the local voice channel 21.

Since the local voice channel 20, 21 is connected, as herein described, to the long-distance voice channel 10, the audio-output of the receiver

35 will thus be supplied to the long-distance voice channel as well as the local voice channel at Station No. 1. Energizing of the local control energy channel 23, 22 is effective to cause operation of the relay 30 at the operating site 18 of Station No. 1, this circuit being traceable from the control channel 22 through a conductor 133, a pair of normally closed contacts 134 on the relay 29, and a conductor 135 to the operating winding of the relay 30. Operation of the relay 30 is effective, through closure of its contacts 74, to connect the headset 27 at Station No. 1 to the voice channels whereby the message received at the site 19 is reproduced at the operating site 18 of Station No. 1, this latter circuit extending from the terminal 79 of the voice channel 20 through the conductors 78 and 77, the contact 74 on the relay 30, and the conductors 76 and 75 to the hybrid coil 32 to which the input of the amplifier 28 is connected.

Likewise operation of the relay 30 is effective, through closure of its contacts 89, to supply control energy to the long-distance control channel 11 from the control energy source 24 through the conductors 81 and 82, the contacts 80, and the conductor 83 which is connected to the control channel 11. Energization of the control channel 11 from the source 24 is effective, as previously described in connection with the message originating at the microphone 25, to effect operation of the relay 29a at Station No. 2, and through closure of the contacts 84 and 87a on the relay 29a to connect the headset 27a to the voice channel and to connect the source of control energy 24a to the local control channel 22a. Thus the message received at Station No. 1 will be reproduced at the headset 27a at Station No. 2, and energization of the local control channel 22a is effective, as previously described, to connect the transmitter 37a to the voice channels and to turn on the transmitter so that the message received at Station No. 1 will be rebroadcast by the transmitter 37a at Station No. 2 which, in accordance with the assumption that the aircraft-initiated message is being received at only Station No. 1, places Station No. 2 out of range of the transmitting aircraft. Consequently any message received at Station No. 1 will be reproduced at all of the ground stations and will be rebroadcast at stations other than Station No. 1 so as to be available to other aircraft operating over the system outside of the transmitting range of the initiating aircraft.

It will be recalled that initial energization of the relay 55 from the carrier control circuit of the receiver 35 was accomplished through a circuit including the normally closed contacts 106 on the relay 53, and immediately upon operation of the relay 55 a self-holding circuit is completed which extends from the carrier control terminal 41, through the conductors 104 and 136, the contacts 137 on the relay 55 and by way of conductors 138 and 108 to the energizing winding of the relay. Thus the relay 55 will remain energized to maintain the previously described circuits so long as the message is being received by the receiver 35. Immediately upon termination of the message, however, the relay 55 will be de-energized, whereupon the contacts 109 open to interrupt the energizing circuit for the winding of the relay 54 and cause opening of the contacts 127 and 128 to disconnect the audio-output circuit of the receiver and the source of energy 34 from the local voice and control channels 21 and 23.

De-energization of the control channel 23 ef-

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fects de-energization of the relay 57 to reconnect the frequency generator 39 and the frequency controlling equipment 38 to the voice channel 21, as previously described. In addition, de-energization of the control channel 23 effects de-energization of the relay 30 whereupon the previously traced circuits are interrupted at the contacts 74 and 80 to disconnect the headset 27 from the voice channels and to disconnect the source of control energy 24 from the long-distance control channel 11. As previously described, de-energization of the control channel 11 de-energizes the relay 29a at Station No. 2, thereby disconnecting the headset 27a from the voice channels and disconnecting the control energy source 24a from the local control channel 22a at Station No. 2, whereupon the relay 53a at Station No. 2 is de-energized to turn off the transmitter 37a, and the relay 57a is de-energized to re-connect the frequency control equipment 38a to the voice channels for energization by the standard tone produced by the frequency generator 39 at Station No. 1.

Returning now to Station No. 1, de-energization of the relay 55 not only interrupts the energizing circuit for the relay 54 as previously explained, but through closure of the contacts 139 on the relay 55 establishes an energizing circuit for returning the time control switch 36 to its starting position. This energizing circuit extends from the control energy source 34 through the conductors 110, 111, and 140, the contacts 139, and a conductor 141 to the terminal 142 of the time control switch. From this terminal the circuit extends through a conductor 143 to the normally de-energized contact 119 on the contact bank 42 of the time control switch, thus completing a circuit from the contact 119 through the arm 45 and the rectifier 48 to the operating winding of the time control switch. As soon as this circuit is completed, the arms 45, 46, and 47 of the time control switch will move forward one step, thus immediately interrupting the just traced energizing circuit, but upon contact of the arm 45 with the adjacent contact 144 on the bank 42, another energizing circuit will be completed which extends from the source 34 through the conductors 110, 111, 112, and 145 to the terminal 146 of the time control switch, and from this terminal through conductors 147 and 148, the contact 144, the movable arm 45, and the rectifier 48 to the operating winding 116. Thus the time control switch will continue its stepping operation until the contact arms 45, 46, and 47 return to the position shown in the drawing, the last energizing circuit for the time control switch being interrupted as soon as the arm engages the dead contact 149 on the bank 42. Thus it will be seen that immediately upon termination of the aircraft-initiated message, all of the equipment at each of the ground stations will automatically return to its normal position, and the standard frequency tone produced by the generator 39 will again be applied to the voice channels to energize the frequency control equipment at each of the stations.

In the above-described operation it was assumed that the aircraft-initiated message was received only at Station No. 1. Under such conditions the message will be reproduced at all of the ground stations but will be rebroadcast only at stations other than the one where it is being received. It will be understood, however, that conditions will arise in the operation of systems embodying this invention wherein an aircraft-

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initiated message may be received at more than one ground station. In Fig. 2 a system is shown which includes four ground stations, 12, 13, 14, and 15, the transmitting range of the stations being respectively indicated by the curves 12', 13', 14', and 15'. Although the patterns may be somewhat different, these curves may also be taken as approximations of the receiving range of the stations, or in other words, transmitting range of aircraft operating over the system. Thus an aircraft operating at the point designated X in Fig. 2 would, when transmitting, be able to communicate directly only with station 13, and the message would be forwarded from station 13 to the other stations 12, 14, and 15 in the manner just described, station 13 corresponding to Station No. 1 in this previous description, and each of stations 12, 14, and 15 corresponding to Station No. 2.

On the other hand, if the transmitting aircraft is operating at the point Y in Fig. 2, the transmitted message would be received not only at station 13, but also at stations 12 and 14. Consequently, unless special means were provided, each of these stations would, upon receipt of the message, attempt to supply audio and control energy to the voice and control energy channels, which might result in objectionable interference. In accordance with the embodiment of the invention shown, the possibility of such interference is prevented, and only one of the stations receiving the message supplies the control energy and the audio to the voice and control energy channels for transmission throughout the rest of the system. This is accomplished by assigning different time settings to the time control switches at all of the stations that lie within the range of the transmitting aircraft. Thus in Figs. 1a and 1b it will be observed that the time control switch 36 operates through four steps before the contact arm 45 engages the normally dead contact 119 in bank 42, while in the time control switch 36a the arm 45a need only move through three steps before engaging the corresponding contact 119a. Thus when 60-cycle control energy is employed, the time control switch 36a will have a setting of $\frac{3}{60}$ of a second, while the time control switch 36 has a setting of $\frac{4}{60}$.

In the system of Fig. 2, for example, station 12 might be assigned a time setting of $\frac{3}{60}$ of a second; station 13 a setting of $\frac{4}{60}$; station 14 a setting of $\frac{2}{60}$; and station 15 would then have a setting of $\frac{3}{60}$, the same as station 12, since these two stations are sufficiently spaced so that they would not, at the frequencies employed, ever receive the same signal from an aircraft. Referring again to Figs. 1a and 1b, it will be assumed that an aircraft-transmitted message is received at both Station No. 1 and Station No. 2. As previously explained, the receivers 35 and 35a thereupon supply control energy from the carrier control circuits to energize the relays 55 and 55a, whereupon the time switches 36 and 36a begin operating. As soon as the time switch 36a completes its three-step cycle, the relay 54a will be energized through the contact bank 43a and the contact arm 46a, as previously described in connection with the time switch 36, whereupon control energy and the audio-output of the receiver 35a will be supplied to the voice channels and the control channels throughout the system. This will result in connection of all of the headsets 27 and 27a to the voice channels, in disconnection of the frequency control equipment 38 and 38a and the standard tone generator 39 from the voice

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channels, and in operation of the relay 53 at Station No. 1 to connect the audio-input of the transmitter 37 to the voice channels and to turn on the transmitter, all as previously explained in connection with a condition wherein the message was received only at Station No. 1, the operation now being reversed because Station No. 2 has the lower time setting.

Inasmuch as Station No. 1 is within the transmitting range of the aircraft, it is undesirable to have this station re-broadcast the message, and consequently means are provided for disabling the transmitter at each of the stations wherein the message is being received even though only one of these stations is supplying the control energy in the audio. This is accomplished by means of the time switch 36 which completes its cycle $1/60$ of a second after the completion of the cycle of the switch 36a. When the contact arm 46 in the bank 43 of time switch 36 engages the contact 120, energization of the relay 54 at Station No. 1 cannot occur because the relay 53 has now operated to open the contacts 125 in the energizing circuit of the relay 54. At the same time, however, the contact arm 47 engages contact 150 on contact bank 44 and completes an energizing circuit for relay 56. This energizing circuit extends from the control energy source 34 through conductors 110, 111, 112, and 145, terminal 146, conductors 147 and 151, contact 150, contact arm 47, conductor 152, terminal 153, conductors 154 and 155, contacts 156 on relay 53, which contacts are now closed due to the fact that relay 53 has been operated by the control energy supplied from Station No. 2, and by way of conductors 157 and 158 to the operating winding of the relay 56. Operation of the relay 56 is effective to turn off the transmitter 37 by opening contacts 98, which contacts form a part of the previously closed on-and-off circuit of the transmitter. Thus even though the relay 53 has operated so as to prevent audio from the receiver 35 being supplied to the voice channels through the relay 54, the transmitter 37 is rendered inoperative by operation of the relay 56, which means that the message received at Station No. 2 will be rebroadcast only at stations outside the receiving range and not by any station wherein the receiver is directly receiving the message. Closure of the relay 56 is effective to establish a self-holding circuit which extends from the junction of the conductors 154 and 155 in the previously traced energizing circuit, through a conductor 159, the contacts 160 on the relay 56, and conductors 161 and 158 to the operating winding of relay 56. Thus the relay 56 will remain energized so long as the associated receiver is receiving the message, and will be deenergized only when the relay 53 operates as previously described to cause the time switch to return to its normal position, the contact arm 47 then moving off the contact 150 to interrupt the energizing circuit of the relay 56.

As will be apparent to those skilled in the art, whenever one of the transmitters, for example the transmitter 37 at Station No. 1, is turned on either by initiation of a message at one of the ground stations or by reception of an aircraft-initiated message at some station outside of the receiving range of Station No. 1, the receiver 35 at Station No. 1 will receive the transmission from its associated transmitter and would, in the absence of proper preventative circuits, immediately function to energize the time switch 36 and disable the transmitter through the relay 56, whereupon reception by the receiver 35 would

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cease and relay 56 would be de-energized to turn on the transmitter again, thus causing a pumping action between the associated receiver and transmitter.

Such an objectionable condition is prevented in systems embodying the present invention by the provision of the normally closed contacts 106 on the relay 53, which contacts form a part of the energizing circuit for the relay 55 which controls the time switch. Thus whenever the transmitter 37 is turned on by operation of the relay 53 prior to the reception of a message at the receiver 35, the energizing circuit for the relay 55 is opened and the receiver 35 is rendered incapable of energizing the relay 55 whereby the time switch 36 and the relay 56 remain de-energized. If, however, the relay 53 does not operate to turn on the transmitter until after the relay 55 has been operated by the reception of a message, the contacts 106 are ineffective to de-energize the relay 55 due to the previously traced self-holding circuit which includes the contacts 137. Accordingly, the receiver control circuits, which are normally operable to disable the transmitter whenever a message is being received, are not effective when the received message is being transmitted at the same station.

As previously explained, adjacent ground stations in systems embodying this invention although located out of range of each other at ground level, are close enough to provide, as shown in Fig. 2, overlapping zones wherein an aircraft may receive messages from two or more ground stations, which would of course result in an interfering audible heterodyne unless all of the ground station transmitters are held exactly on frequency. Such exact frequency control could be accomplished by energizing the local frequency control equipment at each station continuously from a common standard frequency tone supplied over a separate voice channel capable of transmitting such a tone. However, the stand-by toll charges on such an additional voice channel result in undesirably high fixed operating charges, and in accordance with the present invention the necessity for an additional voice channel is obviated by employing the same voice channel for transmission of the standard frequency tone as is employed for transmitting the audio-frequency voice currents, the standard tone being transmitted only during intervals when no message is being transmitted. With this arrangement the local frequency control equipment at the various stations is relied upon to hold the frequency during the short intervals of message transmission. Absolute frequency control cannot thus be obtained, however, and in accordance with the present invention the assigned frequency channel is divided into a plurality of subchannels all of which lie within the band-pass channel of the aircraft receivers but which have a sufficient frequency separation so that the heterodyne obtained upon simultaneous reception of two such subchannel frequencies is sufficiently high in frequency to permit ready filtering at the receiver. For example, if the aircraft receivers are designed, in accordance with standard design practice, to provide a normal band pass of 50 kilocycles, and proper allowances are made for the normal tolerance of the receiver crystals and the standard frequency tone, as well as for certain other known variable factors, a usable channel approximately 25 kilocycles in width will remain, which may be subdivided into four subchannels having a fre-

quency separation of approximately 8 kilocycles, and these subchannel frequencies are assigned to adjacent ground stations.

If the stations in a system embodying the present invention are located geographically in approximately a straight line with sufficient distance separation between stations so that alternate stations would provide no overlapping signals zones, only two subchannel frequencies would be required. However, if as shown in Fig. 2, the distance between such stations is such as to permit overlapping between signals transmitted from stations 12 and 14, for example, three subchannel frequencies would be required, as indicated in Fig. 2. If the system should include stations arranged so as to provide a crossover, four subchannel frequencies would be required, and although more than four subchannels could be achieved by accepting a lower heterodyne beat note at the receivers, it has been determined that four subchannel frequencies should take care of substantially all required network arrangements. With the spaced subchannels assigned to the various stations as indicated above, exact frequency control is not required, and variations of plus or minus 500 cycles or even more may be tolerated. This is achieved in systems embodying the present invention either by the use of close tolerance quartz crystals at each station for holding the respective transmitters on the assigned subchannel frequencies within the permissible variation, or by providing the frequency controlling equipment 38 and 38a at the various stations and employing the standard frequency tone to maintain this frequency controlling equipment exactly on frequency except during the short intervals of message transmission. In the event that close tolerance quartz crystals of sufficient accuracy are available and are employed in the system, the standard frequency generator 39, the frequency control equipment 38, and the control relays and circuits therefor, now to be described, may be omitted from the system.

Referring to Fig. 3 of the drawing, the frequency controlling equipment 38 for supplying control frequency to the transmitter 37 is shown diagrammatically as including a local oscillator 162 for producing the frequency necessary to insure operation of the transmitter at the assigned subchannel frequency. The oscillator 162, which is of standard construction, is shown as including a crystal 163 and a variable padding condenser 164, the output of the oscillator being connected to the control frequency terminal 51 (Fig. 1a) of the transmitter 37 by a conductor 165. The standard frequency tone produced by the frequency generator 39 is supplied, as previously explained, to the frequency control equipment 38 through the conductor 64, where it is multiplied in a suitable frequency multiplier 166 to a frequency which differs, by a selected audio-frequency difference, from the frequency which the oscillator 162 is intended to hold. The multiplied frequency is then fed, as indicated in Fig. 3, to a suitable detector or mixer 167, where it is heterodyned with the output of the oscillator 162 to provide sum and difference beat-note frequencies, the oscillator being connected to the detector 167, as indicated, by the conductor 168. The difference frequency beat note appearing at the output of the detector 167 is selected by a suitable audio-frequency band-pass filter 169 and is amplified in a suitable amplifier 170 before being fed to the input terminal 171 of a discriminator 172.

The discriminator 172 is constructed to operate with a crossover frequency equal to the selected difference between the multiplied standard frequency tone and the frequency on which the oscillator is to be held, and comprises a pair of tuned circuits 173 and 174, respectively tuned to frequencies above and below the crossover frequency, the tuned circuits being connected through oppositely disposed rectifiers 175 and 176 to the opposite ends of a potentiometer 177 which is connected across a pair of condensers 178 having a mid-point ground connection 179. The arrangement of the various components of the discriminator 172 is such that the potential at the point 180 on the potentiometer 177 will vary between positive and negative values, depending upon the variation of the difference frequency supplied to the discriminator input from the crossover frequency of the discriminator.

Thus if the difference frequency applied to the input of the discriminator is exactly equal to the crossover frequency, zero potential will appear at the output terminal 181, while a variation of the difference frequency above or below the crossover frequency will cause positive or negative potentials, as the case may be, to appear at the output. As shown, the output of the discriminator serves to energize an electric motor 182 having a pair of field windings 183 and 184 connected between the output terminal 181 and a ground connection 185. The rotor of the motor 182 comprises a permanent bar magnet 186 which is mounted on a rotatable shaft 187 that is connected, as indicated by the broken line 188, to the padding condenser 164 of the oscillator 162.

The direction of rotation of the rotor 186 and the shaft 187 is dependent upon the direction of current flow in the field windings 183 and 184, and suitable stops 189 are provided for limiting angular movement or rotation of the shaft. It will thus be seen that the discriminator 172 acts through the motor 182 to adjust the crystal oscillator 162 so that the difference frequency obtained by heterodyning the oscillator output with the multiplied standard frequency tone is maintained equal to the crossover frequency of the discriminator. Thus the frequency supplied to the transmitter 37 by the oscillator 162 is held at the desired value, and when the transmitter is turned on, the carrier frequency will be exactly on the assigned subchannel.

The accuracy with which the frequency control will be held depends almost entirely upon the accuracy with which the crossover frequency of the discriminator may be set and held, and the accuracy of the discriminator calibration may be checked by comparison with the standard frequency tone. For this purpose a suitable frequency meter 190 is provided, connected, as shown, through a suitable push-button switch 191, the frequency meter 190 being of the type to indicate the deviation of the difference frequency selected by the band-pass filter from the standard frequency tone. As previously indicated, the standard frequency tone is continuously supplied to the frequency control equipment 38, except during intervals of message transmission, and it has been found that by closely controlling the crystal oscillator 162 through the discriminator, as described above, the transmitting frequency during the short intervals of message transmission will be held within proper limits.

In Fig. 4 there is shown diagrammatically a condition of operation which may, under certain

circumstances, occur in the operation of a communication system embodying the present invention as thus far described. The system here shown comprises five ground stations 192, 193, 194, 195, and 196 interconnected by suitable long-distance telephone lines 197, which will be understood as constituting the voice and control channels 10 and 11 of Figs. 1a and 1b. Each of the ground stations comprises a receiver 198 and a transmitter 199, the suffixes *a*, *b*, *c*, and *d* being employed to distinguish the receivers and transmitters at the various stations. Each of the ground stations includes the various components and control means heretofore described in connection with Station No. 1 and Station No. 2 of Figs. 1a and 1b for selectively rendering the receiver and the transmitter effective or ineffective in accordance with the operating condition of the system. In Fig. 4, however, the condition of the receivers and transmitters is represented diagrammatically, for purposes of simplicity, by the position of a multiple position switch 209, which is shown as being adapted selectively to connect the receiver or the transmitter to a suitable antenna, it being understood that the switch 200 is shown merely for diagrammatic purposes, the receivers and transmitters being at all times connected to the antennas, as shown in Figs. 1a and 1b, and being rendered effective or ineffective by proper control of the receiver output and transmitter input circuits.

It will now be assumed that an aircraft 201, operating over the system as shown in Fig. 4, is transmitting a message and that, as indicated by the arrows 202, the aircraft-initiated message is being received at stations 192, 193, and 194. If station 194 has the lowest time setting on its time control switch 36, the receiver 198b will, as previously explained, deliver the audio and control energy to the voice and control channels of the system. As previously described, and as indicated in Fig. 4 by the neutral position of the switches 200 and 200a, both the receivers and the transmitters will be rendered ineffective at stations 192 and 193, which stations are within the transmitting range of the aircraft and have higher time settings. Likewise, as indicated by the positions of switches 200c and 200d, the transmitters 199c and 199d will be turned on at stations 195 and 196 to rebroadcast, as indicated by the arrows 203 and 204, the message received at station 194, stations 195 and 196 being outside of the transmitting range of the aircraft.

Although as previously explained, the ground stations in systems embodying the invention are spaced apart distances in excess of the normal transmitting and receiving range at ground level, unusual terrain or unusual atmospheric conditions may so increase this normal range, as indicated by the extension arrows 205 in Fig. 4, as to cause the rebroadcast message from station 195 to reach the receiver 198b at station 194. Since this is the receiver which is supplying the audio and control energy to the system, a closed loop, as indicated by the loop 206 in Fig. 4, would be formed between the stations 194 and 195 which might cause an objectionable audio sing, and which under certain conditions might lock up the control circuits at station 194 after the aircraft 201 has completed its transmission.

Although this abnormal and objectionable condition may only occur under unusual conditions or at particular points in the system, the invention contemplates as a further aspect thereof the provision of means at the ground stations

for eliminating or reducing to a minimum the possibility of such improper operation. In Fig. 5 a system embodying the invention and including such additional means is shown as comprising ground stations 207, 208, 209, and 210 connected by suitable telephone lines 211. Station 207, as shown diagrammatically, includes a pair of unidirectional antennas 212 and 213 arranged to face in opposite directions, a pair of receivers 214 and 215, and a transmitter 216. It will be understood that station 207 includes the various components and control means illustrated and described as composing Station No. 1 and Station No. 2 of Figs. 1a and 1b, and as in Fig. 4, multiple position switches 200 are employed to indicate diagrammatically the effective or ineffective condition of the transmitters and receivers as determined by the control apparatus. In actuality, the receivers are permanently connected to their respective unidirectional antennas, and the transmitter is permanently connected either to a non-directional antenna or to all of the unidirectional antennas.

The arrangement of the antennas, receivers, and transmitters at each of the ground stations is identical, and the suffixes *a*, *b*, and *c* are employed to distinguish between identical parts of different stations. While only two directional antennas and receivers are shown at each station, it will be understood that three or four such antennas and receivers may be employed, depending upon the geographical arrangement of the various ground stations with respect to each other.

In accordance with this aspect of the invention, each of the ground stations includes control circuits the details of which are shown in Fig. 6, and which will be fully described hereinafter, which control circuits are arranged so that upon the receipt of a message at the ground station, the receiver or receivers with the weaker signal will be disconnected or rendered ineffective by the receiver obtaining the stronger signal. Thus, as shown in Fig. 5, receiver 214 at station 207 will be disconnected and receiver 215 will be receiving the signal transmitted from the aircraft 201, as indicated by the arrows 202. Likewise at station 209, the receiver 215b will be disconnected by the receiver 214b, which is receiving the stronger signal; and at station 208 either one of the receivers 214a or 215a may take over to disconnect the other, the signals being received at the antennas 212a and 213a being approximately equal, since the aircraft is operating directly over station 208. The above-described operation of the receivers takes place before either control energy or audio is applied to the voice and control channels, and if it is assumed that station 209 has the lowest time setting as compared with stations 207 and 208, the receiver 214b will operate to supply audio and control energy to the system, and the receivers and transmitters at stations 207 and 208 will be rendered ineffective, as previously described, due to the higher setting of their time switches. Likewise, as previously described, station 210, being outside the transmission range of the aircraft, will have its transmitter 216c turned on to rebroadcast the message received at station 209 from the aircraft. If under these conditions abnormal terrain or atmospheric conditions should cause an extension of the transmission range of station 210, there will be no closed loop formed because the receiver 215b at station 209 will be ineffective to supply audio or

control energy to the system, and because of the directional characteristics of antenna 212b receiver 214b will not receive the signal from station 210.

In Fig. 6 a portion of a ground station is shown as having three unidirectional antennas 217, 218, and 219 respectively associated with three receivers 220, 221, and 222. It will be understood that the ground station of Fig. 6, which represents any one of the stations 207, 208, 209, or 210 of Fig. 5, is identical with Station No. 1 of Fig. 1a, except that the three antennas and receivers have been substituted for the receiver 35 and its antenna in Fig. 1a. In Fig. 6 only so much of the control equipment of Fig. 1a is shown as is necessary for proper correlation of the three receivers to the remainder of the system. Thus the source of control energy 34, the time control switch 36, and the relays 53 and 54 of Fig. 1a are shown in Fig. 6 either in whole or in part.

Respectively associated with the receivers 220, 221, and 222 are selector units 223, 224, and 225, which function, as heretofore indicated, selectively to lock out two of the three receivers, depending upon which of them receives the strongest signal. Selector unit 223, as shown, comprises an electric discharge tube 226 having a triode section consisting of a plate 227, a cathode 228, and a control element 229. In addition, the tube 226 includes a diode section consisting of the cathode 228 and an anode 230. As shown, the cathode 228 is connected through a suitable resistor 231 to the negative terminal of a battery 232 the positive terminal of which is connected to ground, as indicated at 233. The plate 227 of the triode section is connected through a resistor 234 to the positive terminal of a battery 235 the negative terminal of which is likewise connected to ground. The diode section of the tube is connected in a circuit including the resistor 231 and the battery 232, the anode 230 being connected, as shown, to the operating winding of a relay 236, the opposite terminal of the winding being connected to a resistor 237 which is connected to ground, as indicated at 238.

The battery 235 has a greater voltage than the battery 232, and the resistors 231 and 234 are so adjusted that with zero potential on the control element 229, the cathode 228 assumes a positive potential with respect to ground. Accordingly no current flows in the diode section of the tube 226. This condition of zero grid potential corresponds to the no-signal condition of the receiver 220, the grid being connected through a suitable conductor 239 to the automatic volume control circuit of the receiver. As will be understood by those skilled in the art, the automatic volume control circuit of a conventional receiver supplies a negative bias potential proportional to the strength of the signal being received. When this bias potential is applied to the control element 229, the current flowing in the triode section of the tube decreases in proportion to the biasing potential, causing the cathode to assume a negative potential, whereupon current flows through the diode section in a circuit which includes the winding of the relay 236, the resistors 231 and 237, and the battery 232. The ohmic resistance of the winding of the relay 236 is small compared to the resistor 237, and consequently the potential existing at the junction 240 between the winding and the resistor is nearly the same as the plate voltage of the diode section of the tube.

The relay 236, as shown, includes two sets of normally open contacts 241 and 242 and a set of normally closed contacts 243 for selectively controlling the operation of a pair of relays 244 and 245 which are effective to control the connections of the source of control energy 34 and the audio-output of the receiver 220 to the control energy and voice channels 21 and 23 (Fig. 1a), as will more fully appear hereinafter. The relay 244 is provided with two sets of normally closed contacts 246 and 247 and with two sets of normally open contacts 248 and 249, and the relay 245 includes a single set of normally open contacts 250.

As shown, the selector units 224 and 225 each includes an identically arranged electric discharge tube 226 and corresponding relays 236 and 245. In place of the relay 244 of the selector unit 223, however, the unit 224 includes a relay 251 that, in addition to the contacts 246, 247, 248, and 249 of relay 244, includes another set of normally closed contacts 252 and another set of normally open contacts 253. Selector unit 225 includes, in place of the relay 244 of unit 223, a relay 254 that is identical with the relay 251 except that the normally closed contacts 246 are omitted. Aside from the variation in the number of contacts on the relays 244, 251, and 254, all of the selector units are identical. The connections between the three selector units 223, 224, and 225, as will be explained in detail, are such that the relay 236 at the selector unit for the receiver that is receiving the strongest signal, operates to energize the other relays at that selector unit to connect the audio-output of the associated receiver to the conductor 131 which extends through all of the selector units and terminates at the contacts 128 of the relay 54, as previously explained in connection with Fig. 1a, and to connect the control energy source to the conductor 110 which likewise extends through all of the selector units and which leads, by way of the conductor 111, to the time switch 36, and by way of the conductor 130 to the contacts 127 of the relay 54.

Selective operation of the units 223, 224, and 225 in accordance with the strength of the signal received at the associated receiver is accomplished by interconnecting the junction points 240 of the three units, which interconnection may be traced from the junction 240 at selector unit 223 through a conductor 255 and the contacts 247 on relay 244 to a common conductor or bus bar 256 which extends to the other two units. At unit 224 the conductor 256 is connected through the contacts 247 of the relay 251 and the conductor 255 at that unit to the junction point 240, and at selector unit 225 the conductor 256 is connected through the contacts 247 of the relay 254 and a conductor 257 to the junction 240 at this selector unit.

By means of this common connection between the junction points 240, the particular receiver which is receiving the strongest signal will effectively prevent operation of the relays 236 associated with the other receivers; for example, if the strongest signal is being received at receiver 220, the potential developed by the diode section of the tube 226 of selector unit 223 will be greater than that developed in the diode sections of the other tubes, and since the potential developed at selector 223 is applied through the common connection to the junctions 240 at the other units, the diode sections at the selector units 224 and

225 will be biased-off and the relays 236 at these units will remain inoperative.

When the strongest signal is thus received at receiver 220, and the relay 236 of selector unit 223 operates, the contacts 241 and 242 of the relay close to establish energizing circuits for the relays 244 and 245 at the unit 223, and the contacts 243 of relay 236 open to disable the energizing circuits for the relays 251 and 254 at selector units 224 and 225. The energizing circuit for the relay 244 at unit 223 extends from the positive side of a suitable source of energy, indicated by a conventional plus sign, through the contacts 242, a conductor 258, the energizing winding of the relay 244, a conductor 259, the normally closed contacts 252 on the relay 251 at unit 224, a conductor 260, the normally closed contacts 252 on the relay 254 at unit 225, and by way of a conductor 261 to the negative side of the source of energy which is indicated by a conventional minus sign. The energizing circuit for the relay 245 at selector unit 223 extends from the positive side of the source of energy through a conductor 262, the contacts 241, a conductor 263, and the energizing winding of the relay 245 to the negative side of the source of energy. Although conventional plus and minus signs have been used to indicate the source of energy for the relays in the selector units, this is merely for purposes of simplification, and it will be understood that any suitable source, such as the control energy source 34, may be employed.

Immediately upon energization of the relay 244, the contacts 249 close to connect the audio-output circuit of the receiver 220 to the voice channel of the system, the circuit extending from the receiver 220 by way of a conductor 264, the contacts 249 of the relay 244, the conductor 131, and the contacts 128 of the relay 54, which, as explained in connection with Figs. 1a and 1b, will be energized through the time control switch 36, if this particular station has the lowest time setting of any of the ground stations which are receiving the transmitted signal. Likewise closure of the contacts 248 on relay 244 at selector unit 223 and closure of the contacts 250 on the relay 245 connect the source of control energy 34 to the conductor 110 which extends, as previously explained, to the time control switch 36 and the contacts 127 of the relay 54. This circuit extends from the control energy source 34 through conductors 265 and 266, the contacts 248, a conductor 267, and the contacts 250 to the conductor 110.

Simultaneously with closure of these various contacts, the contacts 247 on the relay 244 at selector unit 223 open to interrupt the common connection between the junction points 240 at the various selector units. This is important in order to insure that once a selector unit has taken control, due to reception of the strongest signal, the other selector units and receivers are locked out for the duration of that particular message. Unless this lock-out were provided, it might happen that after rebroadcast of the aircraft transmitted message is initiated at other ground stations, a signal arriving from an adjacent ground station might be stronger than the aircraft signal and cause one of the other receivers through the discharge tube 226 to produce a potential at the junctions 240 that would bias-off the diode section of the tube that had initially taken control.

It will be observed that whichever of the selector units takes control, operation of the associated contacts 247 in the common connection isolates

the energizing circuit for the relay 236 at that unit to insure that this relay will remain energized through the entire duration of the message. Interruption of the common connection will not prevent operation of the other 236 relays in the event that a stronger signal is later received at other receivers, but such operation of the relays 236 at other selector units will not interfere with the original selector unit because of the manner in which various relays are interconnected.

Assume, for example, that selector unit 223 has taken control and that the relay 236 at selector unit 224 thereafter operates. Closure of the contacts 242 of the relay 236 at unit 224 is ineffective to energize the relay 251, because the energizing circuit which would otherwise be completed is, as will be more fully explained, interrupted at the contacts 243 of the relay 236 at unit 223 and at the contacts 246 of relay 244. Such later operation of the relay 236 at unit 224 will, however, complete an energizing circuit for the relay 245 at unit 224, which circuit extends from the positive side of the source of control energy through the conductors 262 and 268, the contacts 241 at unit 224, and by way of the conductor 263 at that unit to the energizing winding of the relay 245. Closure of the contacts 250 on relay 245 at unit 224 is ineffective to complete any circuit because the contacts 248 on relay 251, which are in series with contacts 250, remain open.

If it is assumed now that the strongest signal is received at receiver 222, then relay 236 at the selector unit 225 will operate to energize the relays 254 and 245 at that unit, and the relays 236 at units 223 and 224 will be biased-off, as heretofore explained, the energizing circuit for the relay 254 at unit 225 extending from the positive side of the source of energy through the contacts 243 of the relay 236 at station 223, a conductor 269, the contacts 246 on the relay 244, a conductor 270, the contacts 243 on the relay 236 at unit 224, a conductor 271, contacts 246 on relay 251, a conductor 272, the contacts 242 on the relay 236 at unit 225, the conductor 258, the operating winding of the relay 254, and the conductor 261 to the negative side of the source of energy. The energizing circuit for the relay 245 at selector unit 225 extends from the positive side of the source of energy through the conductors 262 and 268 to selector unit 225, then through the contacts 241 at unit 225, the conductor 263 and the winding at the relay 245 to the negative side of the source. Closure of the contacts 248, 249 and 250 at selector unit 225 is effective to connect the receiver 222 to the contacts 128 of the relay 54 and to connect the source of control energy 34 to the contacts 127 of the relay 54 and to the time control switch 36, the receiver circuit extending from the receiver 222 through the conductor 264, the contacts 249, and the conductors 275 and 131, and the control energy circuit extending from the source of control energy 34 through the conductor 265 which, as shown, extends through all three selector units and by way of the contacts 248, the conductor 267, and the contacts 250 at unit 225 to a conductor 276 which is connected to the previously mentioned conductor 110 which leads through the conductors 111 and 130 to the time control switch and the contacts 127 on the relay 54.

If now, a stronger signal should be received at receiver 220 so as to effect operation of the relay 236 at selector unit 223, the previously described energizing circuit for the relay 254 at station 225 will be interrupted at the contacts

243 at unit 223. This will be ineffective to de-energize the relay 254 at selector unit 225, however, as the relay will remain energized through a holding circuit which extends from the positive side of the source of energy through the conductors 262 and 268, which latter conductor extends through all three selector units and through the contacts 241 on the relay 236 at unit 225, conductors 263 and 273, the contacts 253 on relay 254, a conductor 277, and by way of the energizing winding of the relay 254 and the conductor 261 to the negative side of the source of energy. Likewise, operation of the relay 236 at unit 224 to open the contacts 243 at that unit will be ineffective to de-energize the relay 254 at unit 225 by reason of the just described holding circuit, and consequently once the relay 236 at unit 225 has taken control, it will retain control and lock out the other units throughout the duration of the message.

Each of the relays 244, 251, and 254 is of the slow-to-release type as indicated diagrammatically by the slugs 278, in order to insure that no matter which of the receivers 220, 221, or 222 has taken control, the other receivers will remain locked out at the end of the aircraft-initiated transmission until rebroadcasting from adjacent stations has ceased. Assume, for example, that selector unit 223 has taken control so that the receiver 220 is supplying the audio and control energy to the system, if now the rebroadcast of the message from an adjacent ground station should reach antenna 218 and receiver 221 with sufficient strength to cause operation of the relays 236 and 245 at selector unit 224, no objectionable results would occur because relay 251 at station 224 will not operate, its energizing circuit being interrupted at the contacts 246 of relay 244 and at contacts 243 of the relay 236 at selector unit 223.

Immediately upon termination of the aircraft transmitted message received at receiver 220, the contacts 243 of the relay 236 at selector unit 223 will close and if the relay 244 should likewise operate immediately to close its contacts 246 an energizing circuit would immediately be established for the relay 251 extending from the positive side of the source of energy through the contacts 243 at unit 223, the conductor 269, the contacts 246 of relay 244, the conductor 270, the contacts 242 of the relay 236 at unit 224 (this relay being closed by virtue of the rebroadcast signal received at receiver 221), conductor 258, the winding of relay 251, conductor 260, contacts 252 on relay 254, and by way of the conductor 261 to the negative side of the source of energy. If this energizing circuit were completed immediately upon cessation of the aircraft initiated message received at receiver 220, the selector unit 224 would immediately become effective to supply control energy to the system and a closed loop, such as the loop 206 of Fig. 4, would be established to lock up the system, even though no message was being transmitted. The slow-to-release character of relays 244, 251 and 254 prevents such a lock-up, however, since the supply of control energy to the system is interrupted by the contacts 250 on relays 245 immediately upon cessation of the aircraft initiated message, and the contacts 246 on the relays 244, 251 or 254, as the case may be, remain open for a sufficient period of time thereafter to permit the disabling of all rebroadcasting stations and the release of all of the relays 236 before the con-

tacts 246 reclose to release the lock-out of the other receivers.

It will be understood that operation of the selector units 223, 224, and 225 to select the proper one of the receivers associated therewith takes place prior to operation of the time control switch, since energy is not applied to the time control switch from the control energy source 34 until after the selecting operation has taken place. If the time control switch at the particular station happens to have the lowest time setting of any station at which the message is being received, the relay 54 will then operate to supply the control energy and the audio from the selected receiver to the control channel and the voice channel. In all other respects the operation is as described in connection with Figs. 1a and 1b.

While we have shown particular embodiments of our invention, it will be understood, of course, that we do not wish to be limited thereto since many modifications may be made, and we therefore contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of our invention.

Having thus described our invention, what we claim and desire to secure by Letters Patent is:

1. A system for two-way radio communication between aircraft and ground over distances in excess of the normal range of transmission and reception at the frequency of said communication, comprising a plurality of ground stations spaced apart distances greater than said range at ground level but close enough to provide overlapping zones of ground-transmitted signals at the usual aircraft altitudes and to permit simultaneous reception at a plurality of ground stations of aircraft-initiated signals transmitted at said altitudes, conductor means extending between said stations providing a voice channel capable of two-way transmission of audio-frequencies and a control energy channel, a normally inoperative radio receiver, sound reproducer and radio transmitter at each of said stations, each of said radio transmitters being operable at a frequency within the aircraft receiver band pass acceptance channel at an assigned frequency, means including said channels and automatically responsive to the initiation of a message at any one of said ground stations for causing said sound reproducers and said radio transmitters to become operative to reproduce and broadcast said message at each of said stations, and means including said channels automatically responsive to the reception of an aircraft-initiated message at any one of said stations for causing the radio receiver at said one station and the sound reproducers at all stations to become operative to reproduce said message at all of said stations and for causing only the radio transmitters in stations outside the range of said initiating aircraft to rebroadcast said message.

2. A system for two-way radio communication between aircraft and ground over distances in excess of the normal range of transmission and reception at the frequency of said communication, comprising a plurality of ground stations spaced apart distances greater than said range at ground level but close enough to provide overlapping zones of ground-transmitted signals at the usual aircraft altitudes and to permit simultaneous reception at a plurality of ground stations of aircraft signals transmitted at said altitudes, a conductor voice channel capable of two-

way transmission of audio-frequencies extending between said stations, a conductor control energy channel extending between said stations, a normally inoperative radio receiver, sound reproducer and radio transmitter at each of said stations, each of said radio transmitters being operable at a frequency within the aircraft receiver band pass acceptance channel at an assigned frequency, switching devices at each station automatically responsive to the initiation of a message at any one of said ground stations to cause the transmission of audio and control energy over said channels for effecting operativeness of the sound reproducers and the radio transmitters to reproduce and broadcast said message at each of said stations, and switching devices automatically responsive to the reception of an aircraft-initiated message at any one of said stations to cause the transmission of audio and control energy over said channels for effecting operativeness of the radio receiver at said one station only and of the sound reproducers at all stations to reproduce said message at all of said stations and for effecting operativeness of the radio transmitters only at stations outside the range of said initiating aircraft to rebroadcast said message.

3. A system for two-way radio communication between aircraft and ground over distances in excess of the normal range of transmission and reception at the frequency of said communication, comprising a plurality of ground stations spaced apart distances greater than said range at ground level but close enough to provide overlapping zones of ground-transmitted signals at the usual aircraft altitudes and to permit simultaneous reception at a plurality of ground stations of aircraft signals transmitted at said altitudes, conductor means extending between said stations providing a voice channel capable of two-way transmission of audio-frequencies and a control energy channel, a normally inoperative radio receiver, sound reproducer and radio transmitter at each of said stations, each of said radio transmitters being operable at a frequency within the aircraft receiver band pass acceptance channel at an assigned frequency, means including said channels and automatically responsive to the initiation of a message at any one of said ground stations for causing said sound reproducers and said radio transmitters to become operative to reproduce and broadcast said message at each of said stations, and means automatically responsive to the reception of an aircraft-initiated message at adjacent ones of said stations and including timing means having different settings at adjacent stations for disabling the receiver at all but one of said adjacent stations for effecting operativeness of the sound reproducing means at all stations to reproduce said message at all of said stations and for effecting operativeness of the transmitters only at stations outside the range of said initiating aircraft to rebroadcast said message.

4. A system for two-way radio communication between aircraft and ground comprising a plurality of ground stations each of which includes a transmitter and a receiver, said stations being spaced apart distances greater than the normal effective range of said transmitters at ground level but close enough to provide overlapping signal zones at the usual aircraft altitudes, means providing a long-distance voice channel capable of two-way transmission of audio-frequencies

and extending between said stations, conductor means providing a control energy channel between said stations, sound pickup and sound reproducing means at each of said stations, selectively operable means at each station for connecting the pickup means at that station to said voice channel and for simultaneously supplying control energy to said control channel, automatic means at each of said stations responsive to energization of said control channel for connecting said sound reproducing means and said transmitters to said voice channel and for turning on said transmitters whereby messages originating at any one of said stations are reproduced and rebroadcast at each of said stations, receiver controlled means at each of said stations responsive to reception of a radio signal by the receiver at that station for connecting the receiver output to said voice channel and for energizing said control channel to operate said automatic means, and means at each of said stations for preventing operation of the said transmitter controlling automatic means at that station when said control channel is energized through said receiver controlled means at the same station whereby messages received at any one station are reproduced at all of said stations but are rebroadcast only at stations other than said one station.

5. A system for two-way radio communication between aircraft and ground comprising a plurality of ground stations each of which includes a transmitter and a receiver, said stations being spaced apart distances greater than the normal effective range of said transmitters at ground level but close enough to provide overlapping signal zones at the usual aircraft altitudes, a long distance voice channel capable of two-way transmission of audio-frequencies and extending between said stations, conductors extending between said stations providing a control energy channel, a sound pickup device and a sound reproducing device at each station, selectively operable switching devices at each station for selectively connecting the associated pickup device to said voice channel and for simultaneously energizing said control channel, automatic switching devices at each station responsive to energization of said control channel for connecting said sound reproducers and said transmitters to said voice channels and for turning on said transmitters whereby messages originating at any one of said stations are reproduced and rebroadcast at each of said stations, automatic control devices at each station responsive to reception of a radio signal by the receiver at that station for connecting the receiver output to said voice channel and for energizing said control channel to operate said automatic switching devices, and a discriminating element in the control channel at each station for preventing operation of the transmitter controlling automatic switching device at that station when said control channel is energized through said receiver responsive control device at the same station, whereby messages received at any one station are reproduced at all of said stations but are rebroadcast only at stations other than said one station.

6. A system for two-way radio communication between aircraft and ground comprising a plurality of ground stations each of which includes a transmitting-and-receiving site having a transmitter and a receiver thereat and at least one operating site having a sound pickup device and a sound reproducer thereat, said stations being

spaced apart distances greater than the normal range of said transmitters at ground level but close enough to overlap at the usual aircraft altitudes, means providing long distance and local voice channels capable of two-way transmission of audio-frequencies extending between said stations and between said sites at said stations, means providing control energy channels extending between said stations and between said sites at said stations, means at each operating site for selectively connecting the associated sound pickup device to said voice channels and simultaneously energizing said control channels, automatic means at said sites responsive to energization of said control channels for connecting said sound reproducers and said transmitters to said voice channels and for turning on said transmitters whereby messages originating at any one of said operating sites are reproduced at each operating site and are rebroadcast at each transmitting-and-receiving site, means at each transmitting-and-receiving site responsive to reception of a radio signal by the receiver at that site for connecting the receiver output to said voice channels and for energizing said control channels to operate said automatic means at other sites, and means at each transmitting-and-receiving site for preventing operation of said automatic means at that site when said control channels are energized through said receiver responsive means at the same site, whereby messages received at any one station are reproduced at all operating sites but are rebroadcast only at stations other than said one station.

7. A system for two-way radio communication between aircraft and ground comprising a plurality of ground stations each of which includes a transmitting-and-receiving site having a transmitter and a receiver thereat and at least one operating site having a sound pickup device and a sound reproducer thereat, said stations being spaced apart distances greater than the normal range of said transmitters at ground level but close enough to overlap at the usual aircraft altitudes, a long distance voice channel capable of two-way transmission of audio-frequencies extending between said operating sites, local voice channels connecting said long distance voice channel and each operating site with its associated transmitting-and-receiving site, conductors extending between said stations and between said sites at said stations providing control energy channels, switching devices at said operating sites for selectively connecting the associated pickup device to said voice channels and for simultaneously energizing said control channels, other switching devices at each operating site responsive to energization of said control channels for connecting the associated sound reproducer to said voice channels whereby messages originating at any selected operating site are reproduced at all of said operating sites, switching mechanism at each transmitting-and-receiving site responsive to energization of said control channels from any one of said operating sites for connecting said local voice channels to the audio input of said transmitters and for turning on said transmitters whereby messages originating at any of said operating sites are rebroadcast at all of said stations, receiver controlled devices at each transmitting-and-receiving site responsive to reception of a radio signal by said receiver for connecting the audio output circuit of the receiver to said voice channels and for simultaneously energizing said control channels to operate said other

switching devices at said operating sites whereby messages received at one transmitting-and-receiving station are reproduced at all operating sites, and circuit elements in said local control channels at each transmitting-and-receiving site for preventing energization of said switching mechanism through said receiver controlled device at the same site, said switching devices at other stations operating upon said energization of said control channels through said receiver controlled device at said one station whereby messages received at said one station are rebroadcast at other stations only.

8. A system for two-way radio communication between aircraft and ground comprising a plurality of ground stations each of which includes a transmitter and a receiver, said stations being spaced apart distances greater than the normal effective range of said transmitters at ground level but close enough to provide overlapping signal zones at the usual aircraft altitudes and to permit simultaneous reception at a plurality of stations of a message transmitted from aircraft at said altitudes, means providing a long distance voice channel capable of two-way transmission of audio-frequencies and extending between said stations, conductor means providing a control energy channel between said stations, sound pick-up and sound reproducing means at each of said stations, selectively operable means at each station for connecting the pick-up means at that station to said voice channel and for simultaneously supplying control energy to said control channel, automatic means at each of said stations responsive to energization of said control channels for connecting said sound reproducing means and said transmitters to said voice channel and for turning on said transmitters whereby messages originating at any one of said stations are reproduced and rebroadcast at each of said stations, receiver controlled means at each of said stations responsive to reception of a radio signal by the receiver at that station for connecting the receiver output to said voice channel and for energizing said control channel to operate said automatic means, means at each of said stations for preventing operation of the said transmitter controlling automatic means at that station when said control channel is energized through said receiver controlled means at the same station whereby messages received at any one station are reproduced at all of said stations but are rebroadcast only at stations other than said one station, said receiver controlled means at each station including timing means providing a predetermined time delay between reception of a signal and energization of said channels by said receiver controlled means, the time delay differing at adjacent stations capable of receiving the same signal to provide sequential operation, and means at each station effective upon operation of said transmitter controlling means for rendering said receiver controlled means at that station ineffective to energize said channels whereby only the receiving station having the lowest time delay effects energization of said channels.

9. A system for two-way radio communication between aircraft and ground comprising a plurality of ground stations each of which includes a transmitter and a receiver, said stations being spaced apart distances greater than the normal effective range of said transmitters at ground level but close enough to provide overlapping signal zones at the usual aircraft altitudes, and to permit simultaneous reception at a plurality of stations of a message transmitted from aircraft

at said altitudes, a long distance voice channel capable of two-way transmission of audio-frequencies and extending between said stations, conductors extending between said stations providing a control energy channel, a sound pickup device and a sound reproducing device at each station, selectively operable switching devices at each station for selectively connecting the associated pickup device to said voice channel and for simultaneously energizing said control channel, automatic switching devices at each station responsive to energization of said control channel for connecting said sound reproducers and said transmitters to said voice channel and for turning on said transmitters whereby messages originating at any one of said stations are reproduced and rebroadcast at each of said stations, receiver controlled devices at each station responsive to reception of a radio signal by the receiver at that station for connecting the receiver output to said voice channel and for energizing said control channel to operate said automatic switching devices, a discriminating element in the control channel at each station for preventing operation of the transmitter controlling automatic switching device at that station when said control channel is energized through said receiver controlled device at the same station, whereby messages received at any one station are reproduced at all of said stations but are rebroadcast only at stations other than said one station, said receiver controlled device at each station including a time delay switch, said time delay switches having different settings at adjacent stations to provide sequential operation of said receiver controlled devices, and contacts operable by said transmitter controlling automatic switching device at each station to render said receiver controlled device at that station ineffective to energize said channels, whereby only the receiving station having the lowest time setting effects energization of said voice and control channels.

10. A system for two-way radio communication between aircraft and ground comprising a plurality of ground stations each of which includes a transmitter and a receiver, said stations being spaced apart distances greater than the normal effective range of said transmitters at ground level but close enough to provide overlapping signal zones at the usual aircraft altitudes and to permit simultaneous reception at a plurality of stations of a message transmitted from aircraft at said altitudes, means providing a long distance voice channel capable of two-way transmission of audio-frequencies and extending between said stations, conductor means providing a control energy channel between said stations, sound pickup and sound reproducing means at each of said stations, selectively operable means at each station for connecting the pickup means at that station to said voice channel and for simultaneously supplying control energy to said control channel, automatic means at each of said stations responsive to energization of said control channel for connecting said sound reproducing means and said transmitters to said voice channel and for turning on said transmitters whereby messages originating at any one of said stations are reproduced and rebroadcast at each of said stations, receiver controlled means at each of said stations responsive to reception of a radio signal by the receiver at that station for connecting the receiver output to said voice channel and for energizing said control channel to operate said automatic means, means at each of said stations for

preventing operation of the said automatic means controlling said transmitter at that station when said control channel is energized through said receiver controlled means at the same station whereby messages received at any one station are reproduced at all of said stations but are rebroadcast only at stations other than said one station, said receiver controlled means at each station including time delay means providing a predetermined time delay between reception of a signal and energization of said channels by said receiver controlled means, the time delay differing at adjacent stations capable of receiving the same signal, means at each station effective upon operation of the transmitter controlling means at that station for rendering the receiver controlled means at the same station ineffective to energize said channels, whereby only the receiving station having the shortest time delay effects energization of said channels, and means energizable by said time delay means at the conclusion of its time cycle for disabling the transmitter at that station whereby a message received at a plurality of stations is rebroadcast only at stations outside the receiving range.

11. In a system for radio communication between aircraft and ground, a plurality of ground stations each of which includes a transmitter and a receiver, said stations being spaced apart distances greater than the normal effective range of said transmitters at ground level but close enough to permit simultaneous reception at a plurality of stations of messages transmitted from an aircraft flying at the usual aircraft altitudes, means extending between said stations providing a long-distance voice channel capable of two-way transmission of audio-frequencies and a control energy channel, receiver controlled means at each of said stations responsive to the reception of signals by the receiver at that station for connecting the audio output of said receiver to said voice channel and for energizing said control channel, transmitter control means at each of said stations responsive to energization of said control channel for connecting said voice channel to said transmitter and for turning on said transmitter, said receiver controlled means at each station including timing means providing a predetermined time delay between reception of a signal and energization of said channels by said receiver controlled means, said time delay differing at adjacent stations capable of receiving the same signal, and means at each station effective upon operation of said transmitter control means at that station for rendering the receiver controlled means at that station ineffective to energize said channels, whereby only the receiving station having the shortest time delay effects energization of said channels.

12. In a system for radio communication between aircraft and ground, a plurality of ground stations each of which includes a transmitter and a receiver, said stations being spaced apart distances greater than the normal effective range of said transmitters at ground level but close enough to permit simultaneous reception at a plurality of stations of messages transmitted from an aircraft flying at the usual aircraft altitudes, means providing a long-distance voice channel extending between said stations and capable of two-way transmission of audio-frequencies, means providing a control energy channel extending between said stations, receiver controlled means at each of said stations responsive to the reception of signals by the receiver at that sta-

tion for connecting the audio output of said receiver to said voice channel and for energizing said control channel, transmitter control means at each of said stations responsive to energization of said control channel for connecting said voice channel to said transmitter and for turning on said transmitter, said receiver controlled means at each station including timing means providing a predetermined time delay between reception of a signal and energization of said channels by said receiver controlled means, said time delay differing at adjacent stations capable of receiving the same signal, means at each station effective upon operation of said transmitter control means at that station for rendering the receiver controlled means at that station ineffective to energize said channels, whereby only the receiving station having the shortest time delay effects energization of said channels, and means at each station for preventing energization of said transmitter control means when said control channel is energized through the receiver controlled means at the same station whereby messages received and applied to said voice channel at any one station are rebroadcast only at other stations.

13. In a system for radio communication between aircraft and ground, a plurality of ground stations each of which includes a transmitter and a receiver, said stations being spaced apart distances greater than the normal effective range of said transmitters at ground level but close enough to permit simultaneous reception at a plurality of stations of messages transmitted from an aircraft flying at the usual aircraft altitudes, means providing a long-distance voice channel extending between said stations and capable of two-way transmission of audio-frequencies, means providing a control energy channel extending between said stations, receiver controlled means at each of said stations responsive to the reception of signals by the receiver at that station for connecting the audio output of said receiver to said voice channel and for energizing said control channel, transmitter control means at each of said stations responsive to energization of said control channel for connecting said voice channel to said transmitter and for turning on said transmitter, said receiver controlled means at each station including timing means providing a predetermined time delay between reception of a signal and energization of said channels by said receiver controlled means, said time delay differing at adjacent stations capable of receiving the same signal, means at each station effective upon operation of said transmitter control means at that station for rendering the receiver controlled means at that station ineffective to energize said channels, whereby only the receiving station having the shortest time delay effects energization of said channels, means at each station for preventing energization of said transmitter control means when said control channel is energized through the receiver controlled means at the same station, and means at each station energizable by said time delay means at that station at the conclusion of its time cycle for disabling the transmitter at that station whereby messages received at a plurality of stations are rebroadcast only at stations outside of the receiving range.

14. A system for two-way radio communication between aircraft and ground over distances in excess of the normal range of transmission and reception at those frequencies, comprising a plurality of ground stations spaced apart distances

greater than said range at ground level but close enough to provide overlapping zones of ground-transmitted signals at the usual aircraft altitudes and to permit simultaneous reception at a plurality of ground stations of aircraft signals transmitted at said altitudes, means extending between said stations providing a voice channel capable of two-way transmission of audio-frequencies and a control energy channel, a source of standard frequency at one of said stations, frequency control means at each station operable when energized by said standard frequency to supply controlled frequencies to the transmitters, means normally connecting said source and said frequency control means to said voice channel and automatically responsive to initiation of a message at any one of said stations and to reception of an aircraft-initiated message at any one of said stations for disconnecting said source and said frequency control means from said voice channel, means including said channels and automatically responsive to the initiation of a message at any one of said ground stations for reproducing and broadcasting said message at each of said stations, and means including said channels and automatically responsive to the reception of an aircraft-initiated message at any one of said stations for reproducing said message at all of said stations and for rebroadcasting said message only from stations outside the range of said initiating aircraft.

15. A system for two-way radio communication between aircraft and ground over distances in excess of the normal range of transmission and reception at those frequencies, comprising a plurality of ground stations spaced apart distances greater than said range at ground level but close enough to provide overlapping zones of ground-transmitted signals at the usual aircraft altitudes and to permit simultaneous reception at a plurality of ground stations of aircraft signals transmitted at said altitudes, a voice channel capable of two-way transmission of audio-frequencies extending between said stations, a control energy channel extending between said stations, a source of standard frequency at one of said stations, mechanism at each station operable when energized at said standard frequency to supply predetermined controlled frequencies to the station transmitters, a switching device at said one station normally connecting said source to said voice channel, switching devices at said station normally connecting said mechanism at each station to said voice channel for energization by said standard frequency, said switching devices being operable whenever said control channel is energized to disconnect said source and said mechanism from said voice channel, switching devices at each station automatically responsive to the initiation of a message at any one of said ground stations to cause the transmission of audio and control energy over said channels for reproducing and broadcasting said message at each of said stations, and switching devices automatically responsive to the reception of an aircraft-initiated message at any one of said stations to cause the transmission of audio and control energy over said channels for reproducing said message at all of said stations and for rebroadcasting said message only from stations outside the range of said initiating aircraft.

16. A system for two-way radio communication between aircraft and ground comprising a plurality of ground stations each of which includes a transmitter and a receiver, said stations being

spaced apart distances greater than the normal effective range of said transmitters at ground level but close enough to provide overlapping signal zones at the usual aircraft altitudes, means providing a long-distance voice channel capable of two-way transmission of audio-frequencies and extending between said stations, conductor means providing a control energy channel between said stations, sound pickup and sound reproducing means at each of said stations, a source of standard frequency at one of said stations, frequency control means at each station operable when energized by said standard frequency to supply controlled frequencies to the transmitters, means normally connecting said source and said frequency control means to said voice channel and automatically responsive to initiation of a message at any one of said stations and to reception of an aircraft-initiated message at any one of said stations for disconnecting said source and said frequency control means from said voice channel, selectively operable means at each station for connecting the pickup means at that station to said voice channel and for simultaneously supplying control energy to said control channel, automatic means at each of said stations responsive to energization of said control channel for connecting said sound reproducing means and said transmitters to said voice channel and for turning on said transmitters whereby messages originating at any one of said stations are reproduced and rebroadcast at each of said stations, receiver controlled means at each of said stations responsive to reception of a radio signal by the receiver at that station for connecting the receiver output to said voice channel and for energizing said control channel to operate said automatic means, and means at each of said stations for preventing operation of the said transmitter controlling automatic means at that station when said control channel is energized through said receiver controlled means at the same station whereby messages received at any one station are reproduced at all of said stations but are rebroadcast only at stations other than said one station.

17. A system for two-way radio communication between aircraft and ground over distances in excess of the normal range of transmission and reception at those frequencies, comprising a plurality of ground stations spaced apart distances greater than said range at ground level but close enough to provide overlapping zones of ground-transmitted signals at the usual aircraft altitudes and to permit simultaneous reception at a plurality of ground stations of aircraft signals transmitted at said altitudes, means extending between said stations providing a voice channel capable of two-way transmission of audio-frequencies and a control energy channel, a source of standard frequency at one of said stations, frequency control means at each station operable when energized by said standard frequency to supply predetermined controlled frequencies to the transmitters at said stations, said controlled frequencies at adjacent stations differing from each other to cause said transmitters to operate on subchannel frequencies all of which are within the aircraft receiver band-pass acceptance channel at the assigned frequency but which have frequency separations such as to produce heterodyne beat notes of a frequency high enough to be readily filtered out at the aircraft receivers, means normally connecting said source and said frequency control means to said voice channel

and automatically responsive to initiation of a message at any one of said stations and to reception of an aircraft-initiated message at any one of said stations for disconnecting said source and said frequency control means from said voice channel, means including said channels and automatically responsive to the initiation of a message at any one of said ground stations for reproducing and broadcasting said message at each of said stations, and means including said channels and automatically responsive to the reception of an aircraft-initiated message at any one of said stations for reproducing said message at all of said stations and for rebroadcasting said message only from stations outside the range of said initiating aircraft.

18. In a system of radio communication from ground to aircraft wherein a plurality of ground transmitters are interconnected for simultaneous operation to effect transmission of a message over a zone in excess of the range of any one transmitter and wherein said transmitters are spaced to provide zones of overlapping signals from adjacent stations at the usual aircraft altitudes, the method of preventing interfering audible heterodynes in the reception of aircraft in said overlapping zones, which method comprises providing each aircraft with a receiver for receiving a predetermined band-pass acceptance channel at an assigned frequency and providing adjacent transmitters for transmitting different subchannel frequencies within said acceptance channel, energizing said adjacent transmitters at said respective different subchannel frequencies, and filtering out the resulting heterodyne beat note produced in said overlapping zone at the aircraft receiver.

19. In a system of radio communication from ground to aircraft wherein a plurality of ground transmitter stations are interconnected by a single voice channel for simultaneous operation to effect transmission of a message over a zone in excess of the range of any one transmitter and wherein said transmitters are spaced to provide zones of overlapping signals from adjacent stations at the usual aircraft altitudes, the method of controlling said transmitters which comprises supplying to said voice channel a standard frequency tone, providing a local oscillator for the transmitter at each station for generating a predetermined frequency, controlling the local oscillator at each station in accordance with a function of the standard tone and of the frequency of the local oscillator to maintain the oscillator frequency within a predetermined minimum frequency variation, removing said standard frequency tone from said voice channel upon the initiation of a message at any station to free said voice channel for transmission of said message to each transmitter, whereby said local oscillators are uncontrolled during transmission, and reconnecting said standard frequency tone to said voice channel upon cessation of the message.

20. In a system of radio communication from ground to aircraft wherein a plurality of ground transmitter stations are interconnected by a single voice channel for simultaneous operation to effect transmission of a message over a zone in excess of the range of any one transmitter and wherein said transmitters are spaced to provide zones of overlapping signals from adjacent stations at the usual aircraft altitudes, the method of controlling said transmitters to prevent interfering audible heterodynes in the reception of aircraft in said overlapping zones, which

method comprises providing local oscillators at adjacent stations for generating different subchannel frequencies within the band-pass acceptance channel at the assigned frequency of the aircraft receiver, said subchannels having frequency separations such as to produce heterodyne beat notes of a frequency high enough to be readily filtered out at the aircraft receiver, energizing the local oscillators at the respective adjacent stations to operate the associated transmitters at the different subchannel frequencies, supplying to said voice channel a standard frequency tone, controlling the local oscillator at each station in accordance with a function of the standard tone and of the frequency of the local oscillator to maintain the transmitters on said subchannel frequencies, removing said standard frequency tone from said voice channel upon the initiation of a message at any station to free said voice channel for transmission of audio to each transmitter, said local oscillators being uncontrolled during transmission, and reconnecting said standard frequency tone to said voice channel to reestablish control of said oscillators immediately upon cessation of the message.

21. A system according to claim 1, wherein each ground station includes a plurality of unidirectional antennas respectively directed toward adjacent ground stations, a separate receiver for each of said antennas, and means at each station responsive to the reception of signals at said station for selectively connecting to said voice channel the receiver which is supplying the strongest signal and for disabling the remainder of the receivers at said station.

22. A system according to claim 1, wherein each ground station includes a plurality of unidirectional antennas respectively directed toward adjacent ground stations, a plurality of receivers at each station respectively connected to said antennas, a selector unit associated with each receiver and responsive to the reception of signals for connecting said receiver to said voice channel and supplying control energy to said control channel, and means interconnecting said selector units to permit operation only of the selector unit associated with the receiver receiving the strongest signal whereby the remainder of said receivers at said station are disabled.

23. A system according to claim 1, wherein each ground station includes a plurality of unidirectional antennas respectively directed toward adjacent ground stations, a separate receiver for each of said antennas, and selector means at each station responsive to the reception of signals at said station for selectively connecting to said voice channel the receiver supplying the strongest signal and for supplying control energy to said control energy channel, said selector means being effective to disable the remainder of the receivers at said station and including time delay means for maintaining said receivers disabled for a sufficient time interval after cessation of said signals at said selected receiver to permit disabling of all rebroadcasting stations.

24. A system according to claim 4, wherein each ground station includes a plurality of receivers respectively connected to unidirectional antennas directed toward different adjacent ground stations, and selector means at each station responsive to the strength of signal reception for connecting to said receiver controlled means the receiver that is receiving the strongest signal and

for disabling the remaining receivers at said station.

25. A system according to claim 6, wherein each transmitting-and-receiving site includes a plurality of unidirectional receivers respectively directed toward adjacent ground stations, selector means associated with each of said receivers and responsive to the relative strength of the signals received by said respective receivers for disabling all of said receivers except the one receiving the strongest signal whereby said means for connecting the receiver output to said voice channels and for energizing said control channels is controlled by said one receiver, means effective upon cessation of said strongest signal for deenergizing said control channels, and time delay means for maintaining the disabled condition of said receivers until after all of said other stations have ceased rebroadcasting of said signal.

26. A system for two-way radio communication between aircraft and ground over distances in excess of the normal range of transmission and reception at the frequency of said communication, comprising a plurality of ground stations spaced apart distances greater than said range at ground level but close enough to provide overlapping zones of ground-transmitted signals at the usual aircraft altitudes and to permit simultaneous reception at a plurality of ground stations of aircraft-initiated signals transmitted at said altitudes, conductor means extending between said stations providing a voice channel capable of two-way transmission of audio-frequencies and a control energy channel, a normally inoperative radio receiver, a normally inoperative radio transmitter and a sound reproducer at each of said stations, each of said radio transmitters being operable at a frequency within the aircraft receiver band pass acceptance channel at an assigned frequency, means including said channels and automatically responsive to the initiation of a message at any one of said ground stations for causing the sound reproducers at at least some of said stations to become operative to reproduce said message thereat and for causing the radio transmitters at all of said stations to become operative to broadcast said message at each of said stations, and means including said channels and automatically responsive to the reception of an aircraft-initiated message at any one of said stations for causing the radio receiver at said one station and for causing only the radio transmitters in stations outside the range of said initiating aircraft to become operative to rebroadcast said message, and for causing the sound reproducers at at least some of said stations to become operative to reproduce said message thereat.

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