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Aug. 4, 1942.

C. D. HAIGIS

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TWO-WAY RADIO COMMUNICATION SYSTEM

Filed Dec. 28, 1939

3 Sheets-Sheet 1

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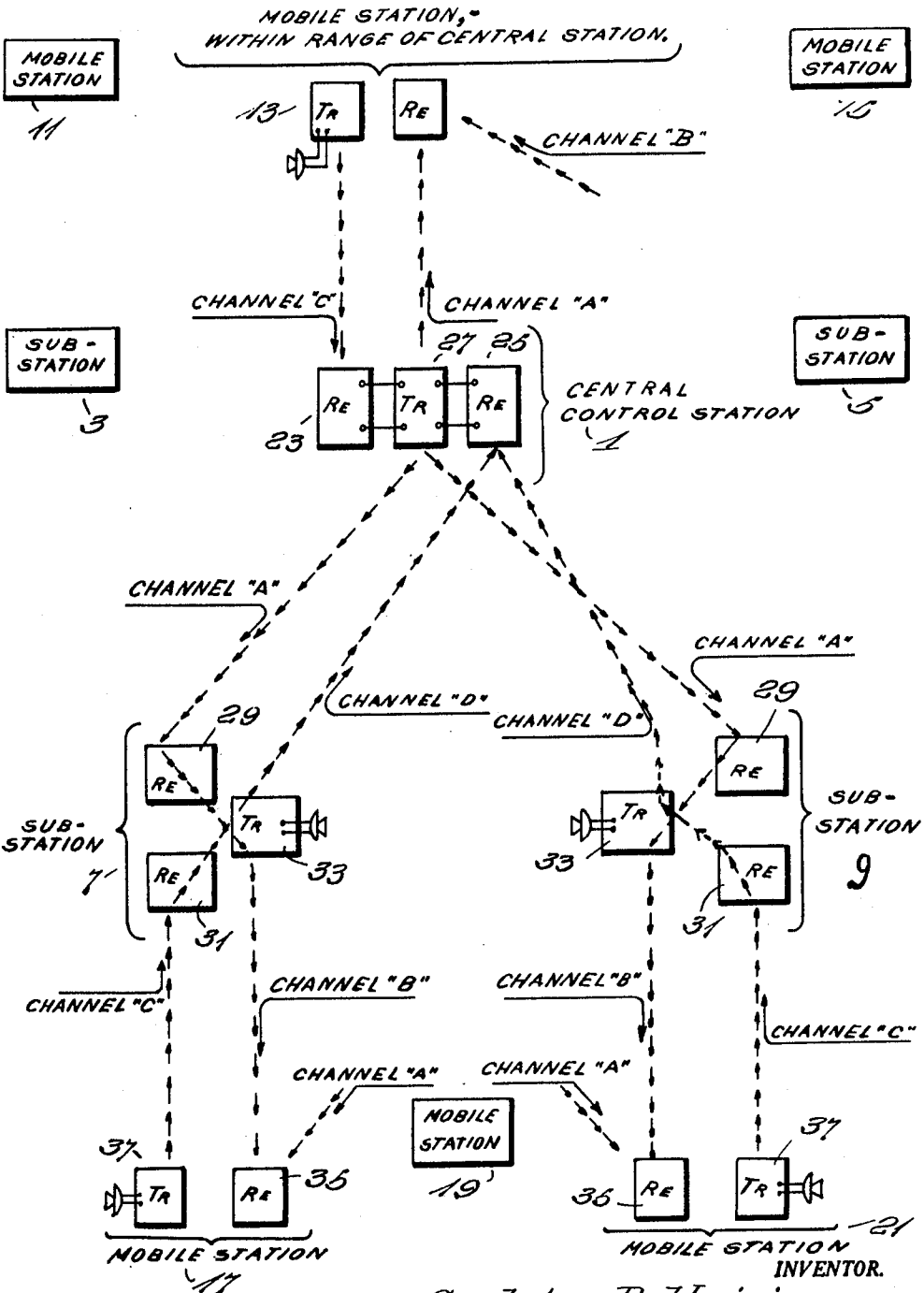


FIG. 1

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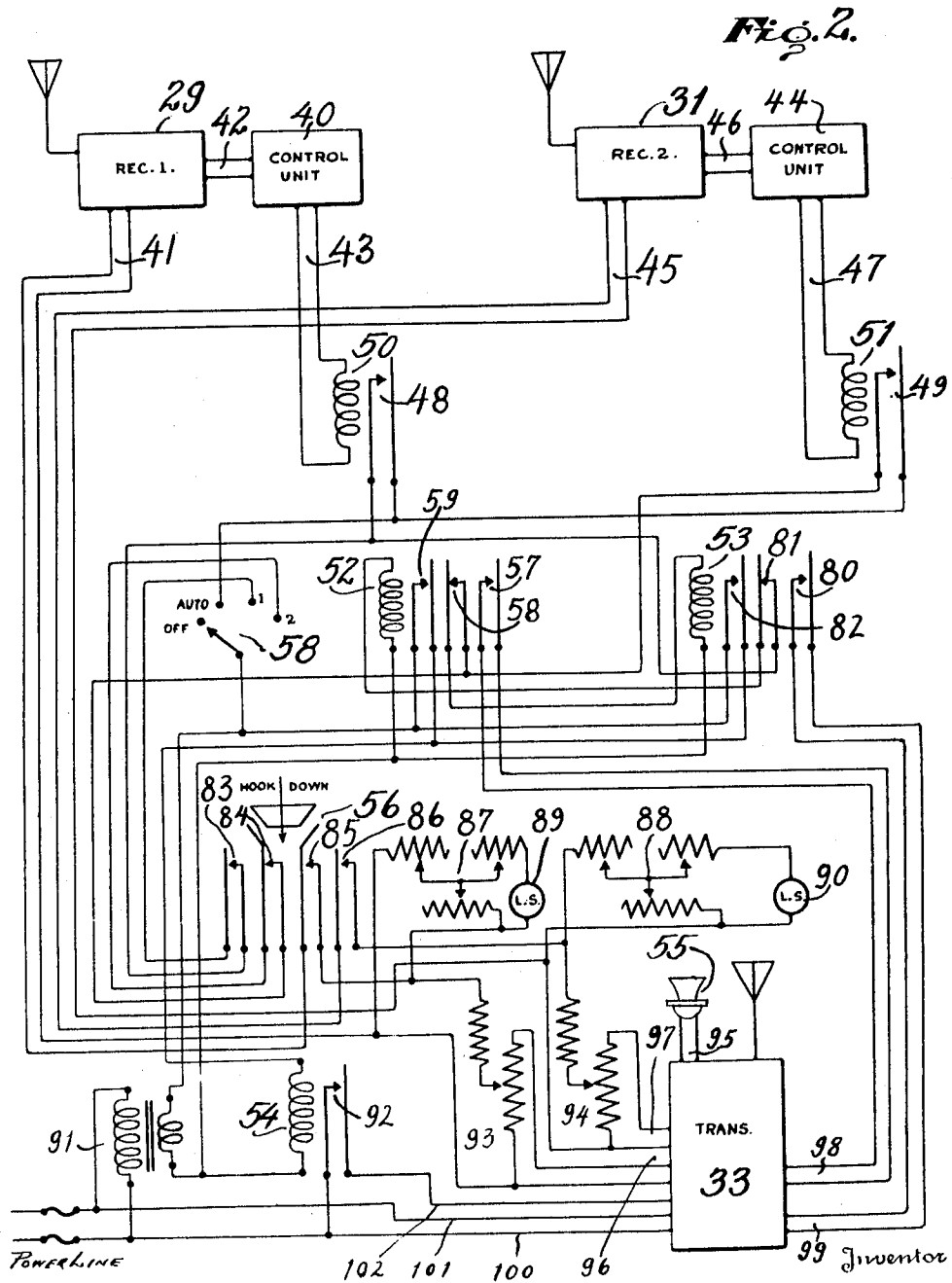
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TWO-WAY RADIO COMMUNICATION SYSTEM

Filed Dec. 28, 1939

3 Sheets-Sheet 2



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By

Ben J. Lehman, Attorney

Aug. 4, 1942.

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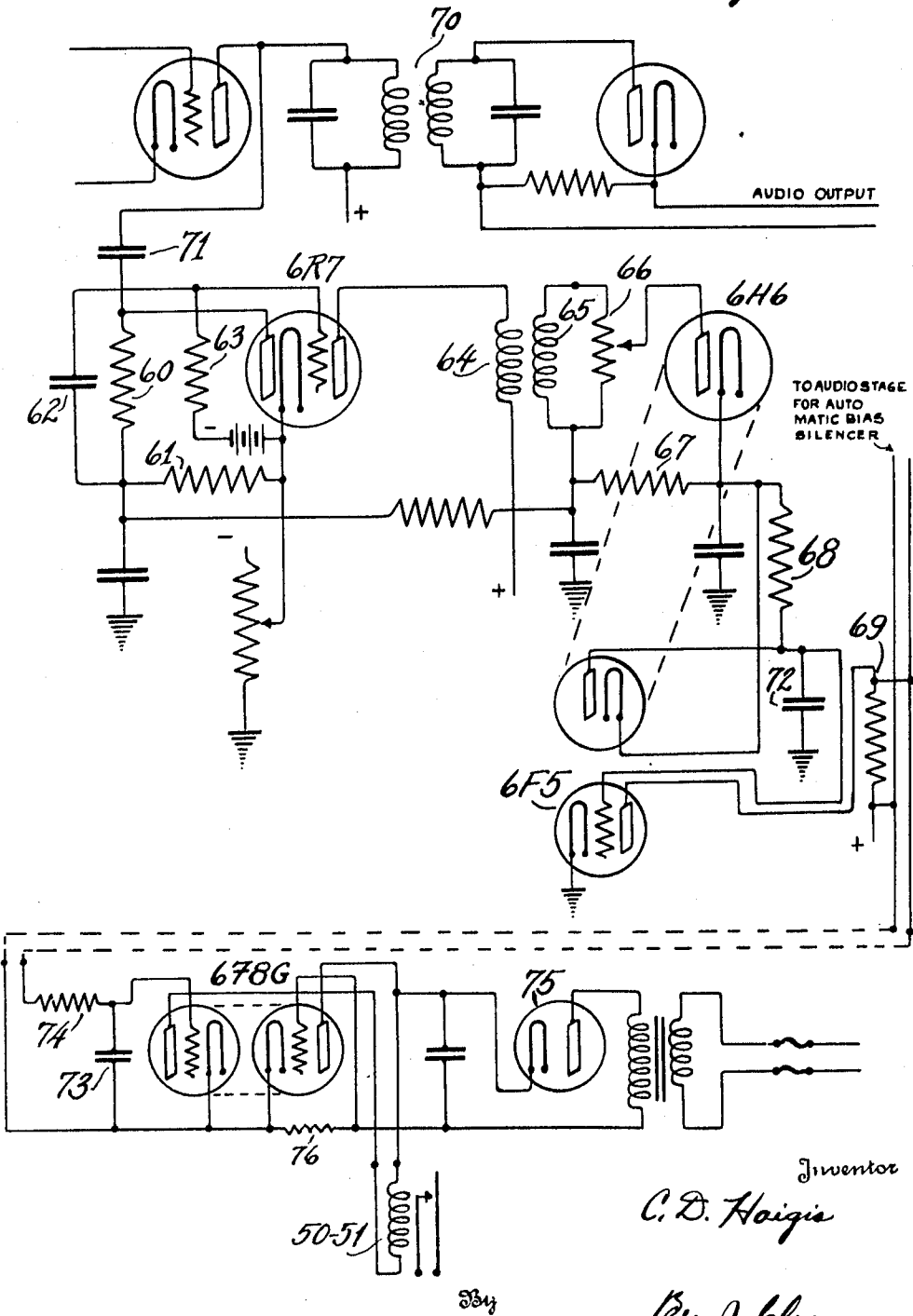
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TWO-WAY RADIO COMMUNICATION SYSTEM

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FIG. 3.



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UNITED STATES PATENT OFFICE

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TWO-WAY RADIO COMMUNICATION
SYSTEMCarleton D. Haigis, Shelburne Falls, Mass., as-
signor of one-fourth to Elmer G. Van Name,
Haddonfield, N. J.

Application December 28, 1939, Serial No. 311,233

8 Claims. (Cl. 250-6)

My invention relates to two-way radio communication systems and, more particularly, to systems comprising fixed transmitting and receiving stations as well as mobile transmitting and receiving stations.

The principal object of my invention is to provide a radio system of the type referred to that shall be particularly useful for statewide police networks or for forest protection purposes although, as hereinafter will be apparent, it has many other possibilities.

Another object of my invention is to provide a two-way radio inter-communicating system whereby a plurality of mobile transmitting-receiving stations may communicate with a central control point and when desired with each other over distances vastly greater than the transmitting-receiving range of any one station.

Another object of my invention is to provide a radio system of the type referred to wherein automatic relaying of radio signals is accomplished without interference and feed-back.

Another object of my invention is to provide a two-way radio system particularly adapted to the utilization of ultra high frequencies both for transmitting and receiving.

Another object of my invention is to provide a radio relay system that shall be substantially immune to static and other interference.

As is well known to those skilled in the art, a mobile station such as a scout car, cannot be equipped with an antenna having sufficiently good radiating characteristics at frequencies of the order of those used for broadcasting which will provide a transmission range of practical value. Of course, by resorting to cumbersome additional motor generators, auxiliary gas engines, extra large storage batteries and the like, to energize a transmitter of sufficient capacity, transmission can be accomplished at the lower frequencies but the mobility of the station would be seriously curtailed because of the weight of the extra apparatus necessary. However, at frequencies of the order of 30 megacycles self resonant antennas, only a few feet in length, may be employed which radiate with very high efficiency so that power for transmission may be obtained from light weight transmitters which can be supplied from the motor-generator, and battery with which the scout cars are factory equipped, without serious drain.

Transmitting equipment designed for mobile use at these ultra-high frequencies can be made compact and light in weight and may be installed in cars of the type used for police service, etc.

Radio power of the order of 15-watts can be radiated without overtaxing the standard electrical equipment supplied with the car. Under these conditions it may be said that the reliable transmitting range in rural areas is of the order of 12-15 miles, altho ranges much greater than this are often possible. In urban areas, where steel buildings may absorb considerable energy and where the noise levels are generally much higher, the range may be reduced to a few miles. Contrary to the general belief, "line of sight" is not necessary for good transmission at frequencies up to well over 100 megacycles due to the fact that frequencies below this figure are diffracted when passing intervening ridges so that in the valleys beyond the signal strength is not greatly attenuated. In the State of New Jersey, where a radio system constructed according to my invention, is in state-wide use at the present time, mobile ranges of 12-15 miles represent a conservative average both in the flat portions toward the southern end of the State and in the mountainous regions toward the northern end.

It will be obvious, of course, that if a statewide police radio system is to be successful, provision must be made for two-way communication between mobile stations, such as scout cars and central headquarters that are separated from each other by distances vastly greater than the transmitting-receiving range of any one station. In other words, resort must be had to automatic relaying of messages from the scout cars to a central control station thru sub-stations properly located throughout the area to be covered. In addition, in order to provide a system universal in scope, provision must also be made for transmission of original messages without verbal relay, between all sub-stations of a group, between any sub-station and the control station, between all mobile units of a group, and between any sub-station and any mobile unit. It should also be clear that inter-communication must be maintained automatically without interference and by use of a minimum number of channels.

I am quite aware of the fact that radio relaying, broadly, is old in the art, whereby an incoming message on one channel is re-radiated on another channel. In accordance with my invention, however, I provide means whereby two-way communication may be maintained between a plurality of mobile stations via intermediate sub-stations and a central control station, the system being so arranged that any station whether mobile or fixed may communicate with any other station, the various transmitting chan-

nels being so automatically selected that feed-back and singing, because of link circuits, is entirely obviated. Specifically, my invention largely resides in the automatic relaying of messages on such channels that said messages are not received back at a relay point from any other point on channels that are able to control or repeat thru the transmitter momentarily in use, and in the provision of means for direct transmission of messages from any relay station as well, to all other points without interference.

Further, in accordance with my invention, I provide a centrally positioned control station and as many substations as are necessary for covering the area desired, which area may be a section of a state under one controlling command or which may be an entire state. To any one group, I assign as many mobile stations, such as scout cars, are as required, which may communicate either directly or through the relaying facilities of the sub-stations with the central station and through it to all other fixed and mobile stations, if desirable.

The novel features that I consider characteristic of my invention are set forth with particularity in the appended claims. The invention itself, however, insofar as its organization and operation are concerned, together with additional objects and advantages therefor, will best be understood from the following description of one embodiment thereof when read in connection with the accompanying drawings. Fig. 1 of the drawings is a greatly simplified schematic view of a portion of a state-wide two-way radio system according to my invention and it must be understood that not only does it exemplify only a minor portion of such a system but that from it have been deleted many portions that would only be confusing. Such deleted portions, however, will be described in detail hereinafter and it is believed that the description thereof will be perfectly understandable to those skilled in the art. Fig. 2 illustrates a detailed diagram of connections of one of the substations and Fig. 3 is a diagram of connections illustrating the operation of the receiver.

Referring now to the drawings, a two-way state-wide radio system, arranged according to a preferred embodiment of my invention, comprises a central control station 1, and a plurality of sub-stations 3, 5, 7, 9, etc., and a plurality of mobile stations 11, 13, 15, 17, 19, 21, etc. Obviously, only a portion of a state-wide system can be shown in the drawings.

The central station comprises at least two receivers 23 and 25 and a transmitter 27. The transmitter 27, either when microphone-controlled or when relaying, radiates on a single ultra high frequency channel A. The receivers 23 and 25, respectively, are tuned to channels C and D and, as hereinafter explained, function to control the operation of the transmitter 27.

Each sub-station as shown in detail in Fig. 2, comprises at least two receivers 29 and 31, tuned respectively to channels A and C a transmitter 33 controlled therefrom and interlocking relays 50, 51, 52 and 53 whereby the said transmitter may be caused to radiate on either channel D or channel B depending on which receiver 29 or 31 first receives and continues to receive a message, or whether a local microphone is utilized. Each mobile unit comprises a receiver 35 tunable at will to channel A or channel B and an independent transmitter 37 that radiates on channel C.

For the sake of simplicity, many of the connections have been omitted from the drawings, but certain of the special features of my system will hereinafter be referred to in some detail.

In operation, a signal sent on channel C out from a mobile station, in range of any sub-station, is relayed by the sub-station on channel D to the central station and reradiated therefrom if desired on channel A to all of the sub-stations within range. At each substation, the signal coming in on channel A is relayed on channel B to the mobile stations in range. Accordingly, each mobile station may communicate with the central headquarters via the nearest substation and through the central station relay to every other substation and thence to all other mobile stations. Thus state-wide coverage and two-way inter-communication may be had although the mobile stations, per se, have only a limited transmitting range.

The receivers at the mobile stations within range of the central station, as exemplified in the drawings by mobile station 5, are preferably tuned to channel A because an intermediate substation is not required.

Naturally, each substation is provided with a microphone 55 for use when direct transmission therefrom is necessary. In that event, the connections are so made through a hook-switch 56, appropriate relays, and a manually operated channel choice switch 58 so that the substation transmitter 33 transmits on channel B to mobile stations within its range and on channel D to the central station 1, whereat the message can be re-radiated on channel A to all other sub-stations and, at such substations, re-radiated on channel B to all mobile stations within range thereof.

At the central station, as well, the transmission of an original message on channel A may be accomplished by a microphone and the proper hook-switch or push-button controlled switches and interlocking relays.

Each station, of course, may be provided with head sets or loud-speakers responsive, respectively, to the receivers thereat.

The channel sequence, from mobile station 17 to mobile station 21, for example, is: C, D, A, B. Channel B, of course, would be received back by the originating station 17 on channel B were it within range of substation 9 but that would cause no trouble because the transmitter and receiver at mobile station 17 are not inter-connected. From mobile station 21 to mobile station 17 and to all other mobile stations, the channel sequence is the same.

The channel sequence, for an original message sent out from a microphone at sub-station 7 or at any other substation to all other substations via the central station is: D, A, B. It, obviously, will be repeated back on channel A to the originating sub-station, as well as to all the other sub-stations, but no trouble will occur, or no link circuits causing singing will be set up between the substation and central because the interlocking devices prevent the receiver tuned to channel A at the sub-stations from feeding the transmitters if they are in use on another channel D. Messages from substation 7 to mobile stations within range, are transmitted on channel B by manual channel choice. Thus, messages of a local character may be handled between any sub-stations and its associated mobile units without burdening the complete system.

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This increases the peak message capacity of the network.

Messages from all mobile stations within range of the central station are received at the latter on channel C and can be relayed on channel A to all sub-stations and via the sub-stations to all other mobile stations on channel B.

From a consideration of the foregoing, it will be apparent, that because of the multiple frequency operation, and the interlocking frequency selecting control by the receivers at a sub-station, no link or feed-back circuits are set up. Messages originating at, or being relayed through a sub-station from a mobile station to the central station for further relay to other points, go out from the sub-station on channel D. They are accepted by the receiver tuned to channel D at central where they are again repeated on channel A to all sub-stations including the originating sub-station, but as before mentioned, no automatic action is possible at the originating sub-station because the channel A receiver at that point is prevented from controlling by the interlocking circuits.

Messages originating at, or being relayed through the central station on channel A, automatically put all sub-station transmitters, not in use on another channel, on channel B and the message is relayed on this channel to the mobile stations. Because of this frequency selecting action, messages originating at, or being relayed by the central station, cannot be received back at the central station since the receiver at that point is tuned to a channel which cannot be set up at a sub-station by a signal emanating from the central station. This completely eliminates the possibility of establishing a link or circulating feed-back circuit between central and a sub-station.

It will be evident, on referring to the diagram, that a mobile station may be received by more than one sub-station and a further object of my invention is to provide a means of eliminating any interference due to this cause. If two sub-stations are automatically put on the air by a mobile station, both would transmit on channel D and be received at central simultaneously on the receiver there tuned to D. The two carriers may heterodyne and interference of a varying degree may result. To eliminate this, means are provided at the sub-stations which put the one receiving the strongest signal on the air first. This in turn actuates the transmitter at the central station the signal from which is received at the sub-station receiving the weaker mobile signal where it takes command and prevents the mobile from relaying through the weaker signal.

At the central station and at each sub-station shown in Fig. 2, the control equipment that puts the transmitter on the air is such that the transmitting frequency, or channel, is determined by the particular receiver that is momentarily active. The connections are such that the first receiver 29 or 31 to get a message for relaying controls the application of power to put the transmitter 33 "on the air" through the operation of control relays 48 or 49, selector relays 50 or 51 and relay 54, and determines the tuning of the tank circuit as well as the selection of the proper frequency control for the master oscillator. At the same time, through the operation of relays 50 or 51 responsive to the active receiver, the other receiver is locked out. Thus, when a message is being received on channel C at a sub-station, automatically putting the transmitter on the air

on channel D the transmitter cannot respond to the receiver tuned to channel A. In addition to preventing the setting up of a feed-back link circuit between a sub-station on the central station, such interlocking prevents signals retransmitted from the central station on channel A from interfering with the operation of the sub-station transmitter which is temporarily being utilized for relaying to the central station a message from one of the mobile stations. The converse of the foregoing, of course, is true, since the sub-station cannot receive on channel C and retransmit on channel D during the time it is transmitting on channel B in response to an incoming message from central on channel A.

The automatic interlocking of the receivers at the central station and the automatic interlocking and frequency selection at the sub-station is an extremely important feature of my invention. In fact, it is the main factor in making the system highly successful for two-way communication over large areas.

In order that the transmitter at any station shall not be put into operation by static or by electrical disturbances of a man-made variety such as ignition, commutator noise etc. nor by periodic variations of these types of disturbances, and shall be controlled only by the first receiver at the station that responds to a continuous carrier wave, I utilize a novel circuit network to provide a control-potential that varies in amplitude a fixed amount despite wide variations in amplitude of the said carrier wave and which responds to weak or carrier waves having low amplitude substantially the same in the presence of a large amount of noise as it does when only a small amount is present.

Furthermore, the connections are such that the rate of change of control potential is a function of the amplitude of the incoming signal, being slower for a weak signal than for a strong one.

Specifically, although other types of tubes may be used, I prefer to utilize a diode-triode of the 6R7 type, a double diode of the 6H6 type and a final triode of the 6F5 type connected in a rectifying and amplifying arrangement to supply a control-potential and to cancel the effect of received noise. The anode of the diode portion of the first tube, the 6R7, is connected conductively to the cathode thereof through two resistors 60 and 61, the junction point of which is connected through a capacitor 62 to the grid of the triode portion. A resistor 63 connected to the grid at one end and to a suitable source of negative potential at the other, provides the proper grid bias for amplification. The primary winding 64 of an output transformer is connected to the anode of the triode portion. The secondary winding 65 of the output transformer is connected by means of a potentiometer slider 66 in series with a resistor 67 to one of the anode-cathode paths of the 6H6 tube, the other anode and cathode being inter-connected through an output resistor 68 which constitutes part of the input impedance of the 6F5 triode. The latter tube is provided with an output resistor 69 across which the control potential appears when the system is in operation.

The anode of the diode portion of the first 6R7 tube is connected to the high side of the last intermediate frequency transformer 70 in the receiver, by way of a blocking condenser 71.

Because of the connections enumerated, intermediate frequency energy produced by the incoming carrier as well as by received noise is

impressed upon and rectified by the diode portion of the 6R7 and unidirectional potentials representative thereof appear across the resistor 61 adjacent to the cathode of the said diode portion, the remaining resistor 60 acting to complete a conductive path for the unidirectional current to the anode. Received noise, therefore, produces a unidirectional potential across the resistor connected to the cathode which potential varies with the strength of the received noise. Superimposed on this potential are the audio components of the noise. These components are impressed upon the grid of the triode portion of the tube through the capacitor 62 connected to the junction point between the two resistors 60, 61. These components, therefore, are amplified by the triode portion and appear as potentials across the primary winding of the output transformer, which has such characteristics that only noise components above a frequency which has a negligible amount of energy from audio modulation are impressed upon the next tube, the 6H6. This tube acting as a rectifier supplies unidirectional potential across the resistor connected in series with it to the potentiometer which is in turn connected across the secondary winding 65 of the transformer. By adjusting the potentiometer 66, this potential obtained by rectification of the selected noise may be made equal to that appearing across the resistor directly connected to the cathode of the first 6R7 tube.

It has been found by experiment that the energy distribution in noises of most types is spread over such a wide frequency spectrum that the potentials appearing across the load resistors of the 6R7 diode and the 6H6 remain nearly alike in magnitude even though the noise level varies over a wide range.

The potentials appearing across the said two resistors are applied in series opposition to the grid of the 6F5 control tube through a time delay circuit consisting of a resistor 68 connected to the grid of the 6F5 and a capacitor 72 connected between the grid and cathode. The second diode section of the 6H6 is connected across the delay resistor 68 and functions as will be further explained.

In normal operation, with noise present, the grid of the 6F5 tube is adjusted at or near zero potential by adjusting a potentiometer, the resistor element of which is included in the connection from the negative terminal of the source of plate potential to ground and the slider of which is connected to the cathode of the 6R7 and therefore to the grid of the 6F5 through the series resistors of the diodes. In such event, the potentials across the output resistor of the diode portion of the 6R7 and the output resistor of the first mentioned diode, connected to the secondary of the coupling transformer remain equal and opposite over wide variations of noise and do not materially affect the potentials of the 6F5 grid. Under these conditions, space current flows in the 6F5 tube and unidirectional potential appears across the output resistor connected to its anode. In practice the output resistor has a magnitude of the order of 20,000 ohms and the potential appearing across it is of the order of 10-volts.

Changes in noise level have no effect on this output potential because of the balance of the potentials appearing across the 6R7 and 6H6 diodes. When a carrier wave is received, however, the potential across the output resistor of the diode portion of the 6R7 is increased although

the potential across the output resistor connected to the secondary of the transformer remains practically the same or may even decrease somewhat if the A. V. C. action of the receiver reduces its sensitivity and, consequently, the amount of noise present at audio frequency. The constants of the circuits are so chosen that a weak signal impresses sufficient negative voltage on the grid of the 6F5 tube to completely block the said tube with consequent disappearance of potential across the output resistor connected to the anode thereof. Because of the selective action of the coupling transformer, audio modulation of the carrier, appearing across the diode load resistor connected to the cathode of the 6R7 tube, has no effect on the potential appearing across the output or load resistor of the 6H6 tube which is connected between the secondary of the transformer and the cathode.

The terminal of the load resistor in the 6H6 diode circuit connected to the secondary winding of the transformer is connected to the junction point between the output or load resistors of the diode portion of the 6R7 tube through an isolating resistor having a resistance of the order of 5,000,000 ohms, said resistor being for stabilizing purposes.

The circuit thus far described prevents received noise and variations of received noise either of steady or transient type from materially influencing the potential appearing across the output resistor of the 6F5 tube but permits changes therein in response to carrier waves only. Even weak signals, if continuous, provide a sufficient change in potential across the output resistor of the 6F5 tube to enable the operation of the transmitter control relays hereinafter to be referred to.

In some instances it is desirable, particularly when there are several receiver-controlled transmitters in one network which may automatically relay signals from mobile or fixed stations to one central point, that the delay in actuating the transmitter be longer, the weaker the signal. For that purpose the grid of the 6F5 tube is bypassed to the cathode thereof by the large condenser hereinabove referred to, which condenser receives its charge through the resistor shunted by the second diode portion of the 6H6 tube.

The grid of the 6F5 tube achieves the negative potential applied to the said resistor only after the cessation of charging current to the by-pass condenser. The 6F5 tube, therefore, requires a longer time to block and the control potential across the output resistor thereof is reduced to zero only after a predetermined delay.

The diode element shunting the resistor which is connected to the grid of the 6F5 tube, offers infinite or very high resistance to applied potentials because of its unilateral conductivity and accordingly it does not effectively shunt the resistor feeding the grid thereof when potential is applied. When potential is removed because of the cessation of a carrier signal, the said diode portion so rapidly conducts away the charge acquired by the by-pass condenser that time delay is provided upon the application of a signal but little or no delay results when the signal ceases.

In actual use the potential appearing across the output resistor of the 6F5 tube, is also utilized to provide blocking grid bias for the first audio frequency amplifier tube in the receiver itself. A "silent standby" unaffected by noise or noise variations and which maintains substantially the

full sensitivity of the receiver even with large amounts of noise present is thus provided and the receiver is quiet except when a carrier wave is received. This method of providing "silent standby" and control potentials, offers great advantages in contrast to systems in common use because of the above described noise neutralizing scheme. In the common types where the 6F5 or similar tube is blocked by rectified intermediate frequency energy noise as well as carrier block the tube and the system must be adjusted so that the maximum noise which occurs at any location will not block the 6F5 tube. Under these conditions, a carrier signal of greater amplitude than the maximum noise ever encountered is necessary to provide control and put the receiver in operation, thus the effective sensitivity of the receiver is greatly reduced, whereas in my system, the maximum sensitivity can be substantially maintained, a very desirable feature especially where it is used to receive mobile stations.

As hereinbefore mentioned, at each station except the mobile stations, there is a plurality of receivers each of which is adapted to control a single transmitter for the purpose of relaying an incoming message. To that end the potential appearing across the output resistor of the 6F5 tube is utilized. The said potential is applied to the grid of one section of a dual triode similar to the 6F8G, said grid being connected to the cathode of the tube by way of a by-pass condenser 73. The constants of the resistor 74 and the by-pass condenser 73 are such that no appreciable time delay is introduced thereby and the connecting resistor is made sufficiently large to prevent shunting of the output resistor 69 of the 6F5 tube. The capacitor 73 connected between the grid and the cathode of the above controlling section of the 6F8G is used merely for stabilizing purposes.

The potential on the grid of the controlling triode section of the 6F8G, changes from its steady value of approximately 10-volts to approximately zero volts independently of the strength of the received signal because even a weak signal completely blocks the grid of the 6F5 control tube. The action of the network therefore is of the "on and off" type, one triode of the 6F8G being completely blocked as in the case of no signal, or having zero grid potential when a signal is received.

A relay winding 50-51 is included in the output circuit of the blocking triode section of the 6F8G tube which is devoid of current when no signal is being received but which actuates its contacts when a carrier wave comes in.

Plate current from this section of the dual triode increases from zero to 10 or 15 milliamperes when a signal is received and reliable rugged relays can be used, thus eliminating the uncertainty attendant upon relays of the more sensitive types that are usually used in similar situations.

Because the entire network connected to the relay is above ground potential by reason of the fact that the lower terminal of the output resistor of the 6F5 tube is connected to the positive terminal of the plate potential source, a small separate tube rectifier 75 is utilized for supplying anode potential to the 6F8G dual triode. The second section of the 6F8G is used as a regulator tube to keep the potential supplied by the rectifier substantially constant whether the controlling section is drawing current or not. To accomplish this, a resistor 76 is connected be-

tween the common cathode terminal of the 6F8G tube and the grid of the second triode section thru which the current supplied by the separate rectifier returns to the said common cathode. When the current through the controlling section of the dual triode is high, the grid of the regulating section becomes more negative thus reducing the current through said regulating triode. Conversely, when the current in the controlling section is reduced to zero by an incoming signal, the grid of the regulating section becomes less negative and more plate current flows in said regulating section. Thus the potential from the rectifier source, applied to the controlling section of the 6F8G can be kept substantially constant whether current flows through this section or not.

The action of the system, therefore, is to provide approximately uniform current thru the relay when in the "on" condition and substantially constant voltage from the separate rectifier.

The relay, of course, may be provided with as many contacts as are desirable for the purpose of changing the transmitter from the "standby" condition to the active condition as well as for the purpose of changing the transmitter frequency by actuating other relays which in turn change the tuning of the various circuits and select the desired crystal.

However, in the preferred arrangement, I use a single pair of contacts on the controlling relay in the plate circuit of the 6F8G tube to actuate other relays which perform the various tuning and selective actions.

Also, I provide means, by interlocking the secondary relays controlled by the relays in the plate circuits of the 6F8G tubes associated with each receiver, whereby the first receiver that picks up a carrier wave obtains control of the transmitter and retains control so long as the carrier wave is being received thereby.

If, for example two receivers, 29 and 31, are provided, each of which is adapted to actuate the transmitter 33, as shown in Fig. 2, the contacts of the output relay 50 or 51 of each 6F8G tube, one for each receiver, control respectively the power supply to two independent relays 52 or 53 each having a multiplicity of contacts. Referring to one of the secondary relays 52, it may be provided with one set of contacts 58 normally closed in series with the other relay winding 53 and two sets of contacts 57 and 59 normally open. When the relay 52 is actuated and the energization thereof continues, the set of contacts 58 in series with the other relay winding opens, to prevent the other receiver from gaining control of the transmitter, and the other two sets of contacts 57 and 59 close. One of the sets of contacts 59 which closes when the relay 52 is energized applies potential to a still further relay winding 54 having normally opened contacts 92, which contacts, when closed complete a circuit that supplies plate potential to the transmitter 33, the cathodes in the tubes of which are maintained heated while the transmitter is "standing by." Another set of contacts 57 closes to shift the tuning of the tank circuit of the final amplifier as for example by actuating other relays within the transmitter which connect an additional shunt capacitor thereto while still another set of contacts within the transmitter 33 switches in the proper crystal control unit.

I also provide a local microphone 55 which may be utilized to control the transmitter on either

of the predetermined frequencies. For that purpose a hook switch 56 having a plurality of contacts 83, 84, 85 and 86 is provided, certain of the contacts 85 and 86 close to connect the audio output of both receivers to the input circuit of the transmitter when in the down position and other contacts may be added to connect the microphone thereto when the hook is in the "up" position.

Furthermore, I provide a manually controlled selector switch 58 whereby the system may be placed in condition for automatic relaying or for transmission from a local microphone on either of the available channels depending upon its position.

In order that the station operator may be able to monitor messages being received whether they are being relayed or not, a loudspeaker 89 or 90 is connected thru a volume controlling T-pad 87 or 88 to the output of each receiver. The output of each receiver is also connected to a second set of adjustable T-pads 93 and 94 which supply audio signals from the various receivers to the transmitter 33 through the connections 96 and 97, respectively for relaying purposes.

The following analysis illustrates the above described operations in detail. When receiver 29 receives a message sent out on channel A, to which it is tuned, it provides at leads 42 a control voltage change as hereinafter described. The voltage change applied to control unit 40, also hereinafter described, energizes the coil of relay 50, causing contacts 48 to close. Similarly, contacts 49 of relay 51, are closed when a signal is received by receiver 31 on channel C. The coil of selector relay 52, is energized by voltage from the secondary of transformer 91 when contacts 48 are closed due to a signal being received on receiver 29, only when the selector switch 58 is set in the "Auto" position and only if relay 53 is not energized and contacts 81 are closed. Similarly, the coil of selector relay 53 is energized when contacts 49 are closed by a signal in receiver 31 only if relay has not been previously energized which would open contacts 58. Thus, it will be seen that if relay 52 is already closed by a signal in receiver 29, it will remain so as long as the signal persists even though a signal is received on receiver 31 during this period because even though contacts 49 close, the coil of 53 cannot be energized, since contacts 58 of relay 52 are open. At the end of the message, when receiver 29 no longer receives the signal, contacts 48 will open and relay 52 is de-energized.

Similarly, when a signal is received by receiver 31 on channel C, contacts 49 of relay 51 close and energize the coil of selector relay 53, provided relay 52 is not energized and its contacts 58 are closed. By this means, a signal in receiver 29 is caused to energize relay 52 provided a signal in receiver 31 has not previously energized relay 53. Conversely a signal accepted by receiver 31, will energize relay 53 provided a signal from receiver 29 has not previously energized relay 52. By this means, either receiver retains control of its selector relay 52 or 53, even though a message is received on the other receiver during the interval of the first received message.

Transmitter 33 is kept in the standby position by power supplied it via leads 100 and 101. When contacts 59, of relay 52 are closed by a signal in receiver 29, or when contacts 82 of relay 53 are closed by a signal in receiver 31, the circuit is closed to the coil of relay 54, which in turn closes contacts 92 and thru lead 102 applies power to put transmitter 33 on the air. In the sub-sta-

tions when it is desirable to cause the transmitter 33 to radiate on channel B when a signal is received on channel A to which receiver 29 is tuned and to radiate on channel D when a signal is received on channel C to which receiver 31 is tuned, contacts 57 of relay 52 and contacts 80 of relay 53 are made to operate frequency changing relays within the transmitter 33 thru leads 98 and 99. These frequency changes can be made by various well known means such as by the energizing of a relay whose contacts act to add capacity to the various tuned circuits and to connect a frequency control unit such as a quartz crystal. Thus thru contacts 57 of relay 52, a signal on receiver 29 will cause transmitter 33 to radiate on a certain desired channel and a signal from receiver 31, thru contacts 80 of relay 53, will cause it to radiate on a second selected channel.

Furthermore, because of the interlocking action explained above, control of the transmitter frequency cannot be obtained by a signal coming into one receiver so long as the other receiver is inactive.

In the central station where the transmitter is caused to radiate on a single channel A when either receiver is active, the frequency selecting contacts 57 of relay 52 and 80 of relay 53 are eliminated and the system functions in the same manner except that the transmitter frequency remains constant.

The selector switch 58, is provided so that automatic control of the transmitter by the receivers 29 and 31 can be broken, in which case the contact of the switch is in the off position. This prevents voltage from transformer 91 from reaching coils of relays 52 and 53 via contacts 48 and 49 of relays 50 and 51. Selector switch 58, also permits manual choice of transmitter channel so that the operator at any station can send a message via microphone 55 and transmitter 33 on either channel. By tracing the circuit from the secondary of transformer 91 thru selector switch 58 when in position 1 and thence thru contacts 83 of the hook switch 56 and thru contacts 81 of relay 53, it will be found that the coil of relay 52 is energized thus putting transmitter 33 on the air on the same channel which would be selected by a signal in receiver 29.

Similarly, when manual selector switch 58 is in position 2, relay 53 is energized and transmitter 33 is put on the air on the same channel which a signal in receiver 33 would cause it to radiate. Contacts 83 and 84 of hook switch 56 are closed only when the microphone is removed from its cradle and since the closure of these contacts completes the circuit from positions 1 and 2 of the manual selector switch to relays 52 and 53, the motion of removing the microphone from its hook or cradle puts the transmitter on the air on the channel selected by switch 58.

The audio output from receivers 29 and 31 passes via leads 41 and 45 thru hook switch contacts 85 and 86 which are closed, when the microphone is in its cradle, to loudspeakers 89 and 90 thru volume controlling T-pads 87 and 88. The audio signal from each receiver is also applied to the transmitter thru the volume controlling pads 93 and 94 via leads 96 and 97 where they are amplified and modulate the carrier wave of the transmitter.

Since the removal of microphone 55 from its cradle on hook switch 56 opens contacts 85 and 86, the audio output from both receivers is disconnected from transmitter 33 during the time that it is being modulated by the local microphone

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55. Also the loudspeakers are disconnected by the opening of contacts 85 and 86 in order to eliminate oscillation which might be sent up by feed-back and to eliminate annoyance to the operator when he is transmitting the message via microphone 55.

From a consideration of the foregoing description of a system constructed according to my invention, it will be apparent that it has numerous advantages. Thru its use, efficient two-way communication may be maintained between each and every one of a plurality of widely separated scout cars and central headquarters, and by further relaying at central headquarters to all sub-stations and thru them to all other scout cars. Furthermore, any sub-station may transmit automatically thru the central station to all other sub-stations.

The system is entirely automatic in operation and is substantially unaffected by the prevailing noise level, by variations of noise, or by transient radio disturbances such as static and the like.

Furthermore, because of the unique manner in which the transmission frequency at each relay station is controlled by the frequency on which a message is first received thereat, the other receiver being temporarily removed from the circuit, all feed back and singing is obviated and uninterrupted two-way communication may be had.

Although I have shown merely a schematic of a portion of a police radio system constructed and arranged according to my invention and have described certain specific features thereof, it will be apparent to those skilled in the art that many modifications may be possible. My invention, therefore, is not to be limited except insofar as is necessitated by prior art and by the spirit of the appended claims.

I claim as my invention:

1. In a short wave radio two way communication network adapted to utilize at least four ultra high frequency channels A, B, C and D, a fixed central control and relay station provided with radio receiving means adapted to selectively receive signals on channel C or channel D to the exclusion of signals on the other channels and a radio relay-transmitter selectively controllable thereby to radiate on channel A, at least one fixed sub-station provided with at least two radio receivers tuned respectively to channels A and C and a radio relay-transmitter selectively controllable thereby to radiate on channel B a message received on channel A and to radiate on channel D a message received on channel C, a plurality of mobile stations each of which is provided with a radio transmitter that radiates on channel C and a radio receiver tunable to channel B or channel A, and means at each sub-station for ensuring uninterrupted relay operation and control of the transmitter thereat by the particular radio receiver that first puts the said trans-

mitter into operation on a selected channel in response to the reception of an incoming message.

2. The invention set forth in claim 1, further characterized in that means are provided at the central station for ensuring uninterrupted relay operation and control of the transmitter thereat by the particular radio receiver that first puts the said transmitter into operation in response to the reception of an incoming message.

3. The invention set forth in claim 1, further characterized in that at the sub-station means for causing a strong incoming signal to energize the transmitter more quickly than a weak signal.

4. In a short wave radio two-way communication network adapted to utilize at least four ultra high frequency channels A, B, C and D, a fixed control and relay station provided with at least two radio receivers tuned respectively to channels C and D and a radio relay transmitter selectively controllable thereby to radiate on channel A, a plurality of fixed sub-stations each of which is provided with at least two radio receivers tuned respectively to channels A and C and a radio relay transmitter selectively controllable thereby to radiate on channel B a message received on channel A and to radiate on channel D a message received on channel C, a plurality of mobile stations each of which is provided with a transmitter that radiates on channel C and a radio receiver tunable to channel B or channel A, and means at each sub-station for ensuring uninterrupted relay operation and control of the transmitter thereat by the particular radio receiver that first puts the said transmitter into operation on a selected channel in response to the reception of an incoming message.

5. The invention as set forth in claim 4, further characterized in that means are provided at the central station for ensuring uninterrupted relay operation and control of the transmitter thereat by the particular radio receiver that first puts the said transmitter into operation in response to the reception of an incoming message.

6. The invention as set forth in claim 4, further characterized in that at each sub-station means are provided whereby a strong incoming signal causes energization of the transmitter quicker than a weak incoming signal, thus preventing the simultaneous operation of a plurality of sub-station transmitters under control of signals from a single mobile station.

7. The invention set forth in claim 1, further characterized in that at the sub-station a microphone and switching means for controlling the transmitter locally so that the message originating at said sub-station may be radiated on either channel B or channel D.

8. The invention as set forth in claim 4, further characterized in that at each sub-station a microphone and switching means are provided whereby the transmitter thereat may be locally controlled.

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