

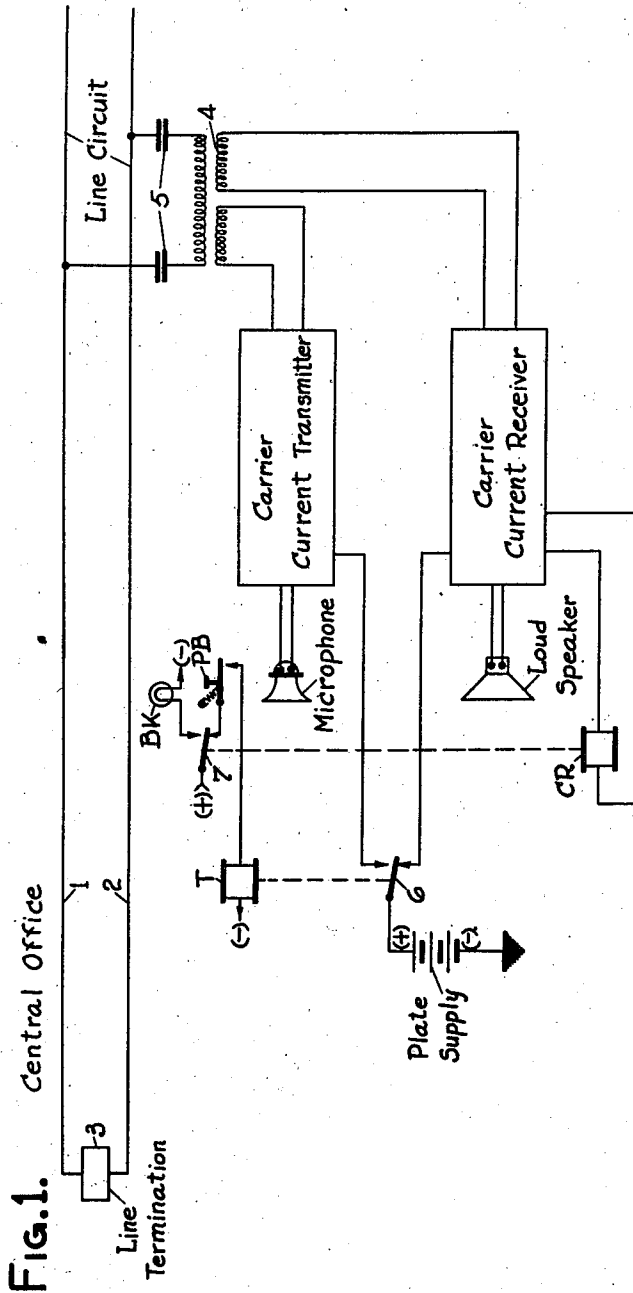
May 10, 1949.

F. B. HITCHCOCK
SELECTIVE RADIO COMMUNICATION SYSTEM
FOR A PLURALITY OF STATIONS

2,469,555

Filed June 19, 1945

4 Sheets-Sheet 1



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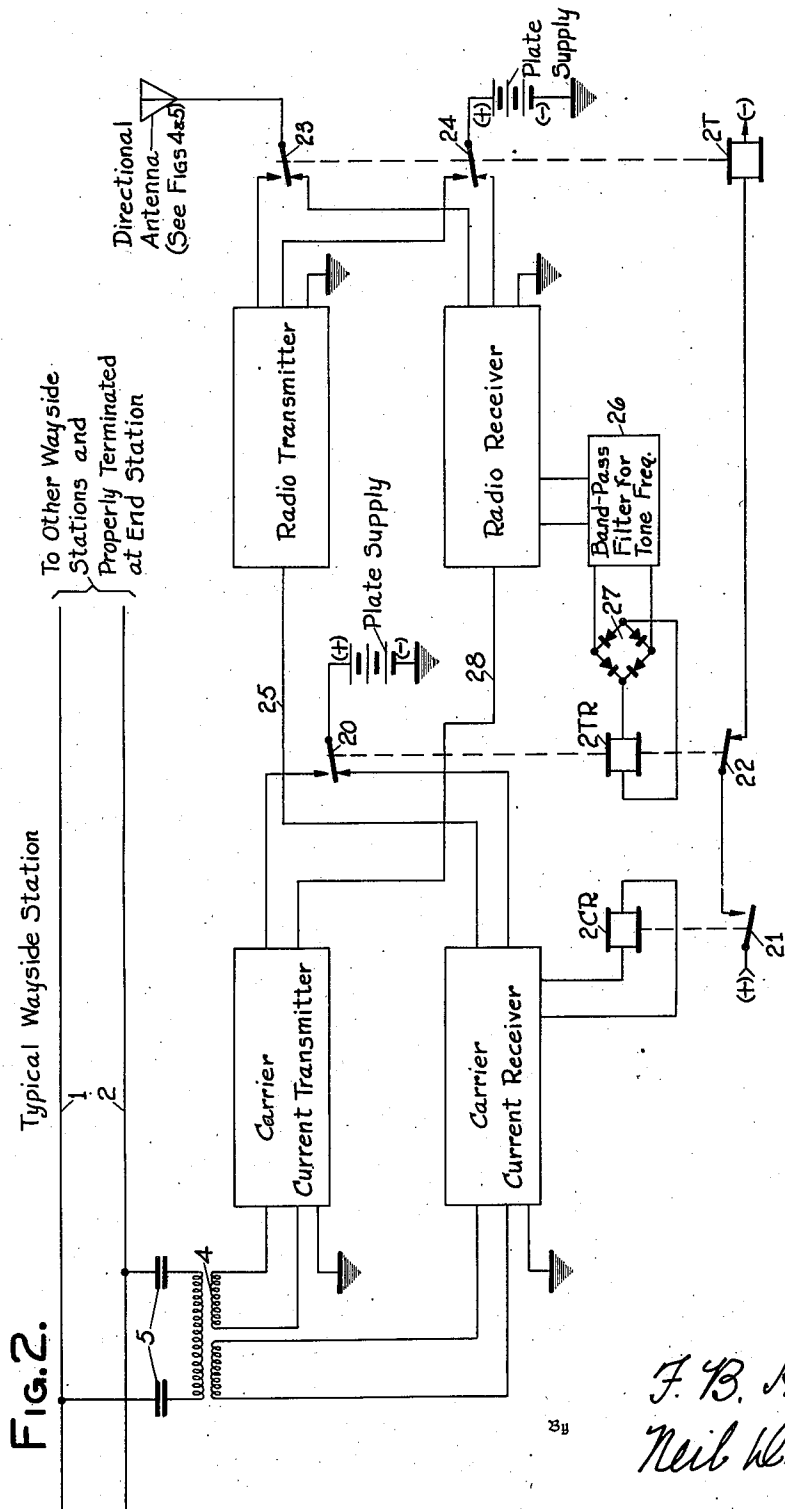
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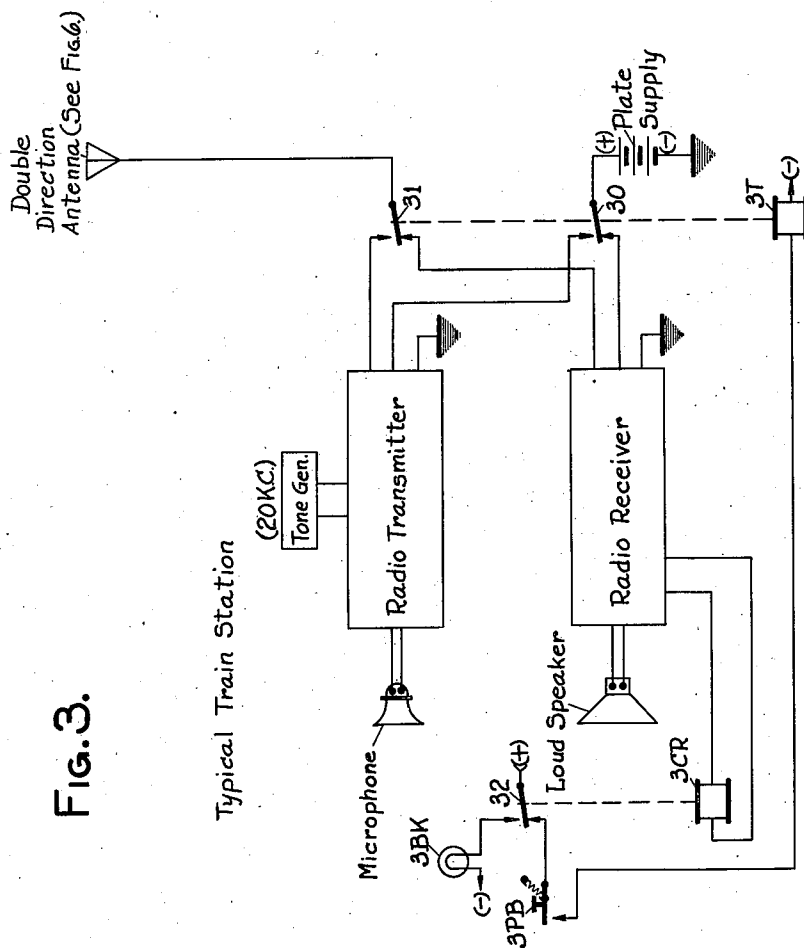
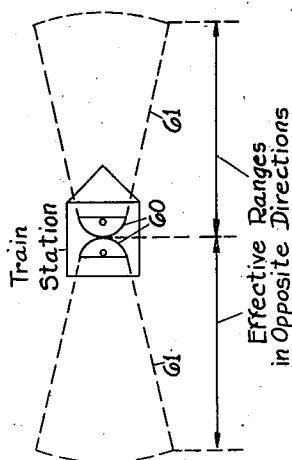


Fig. 6.



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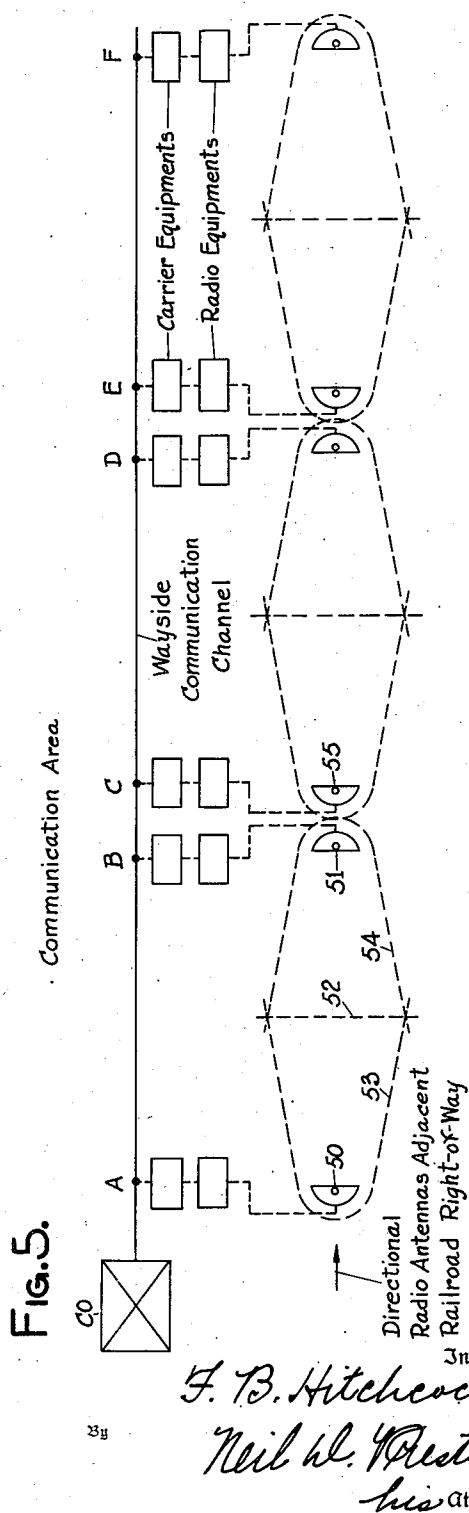
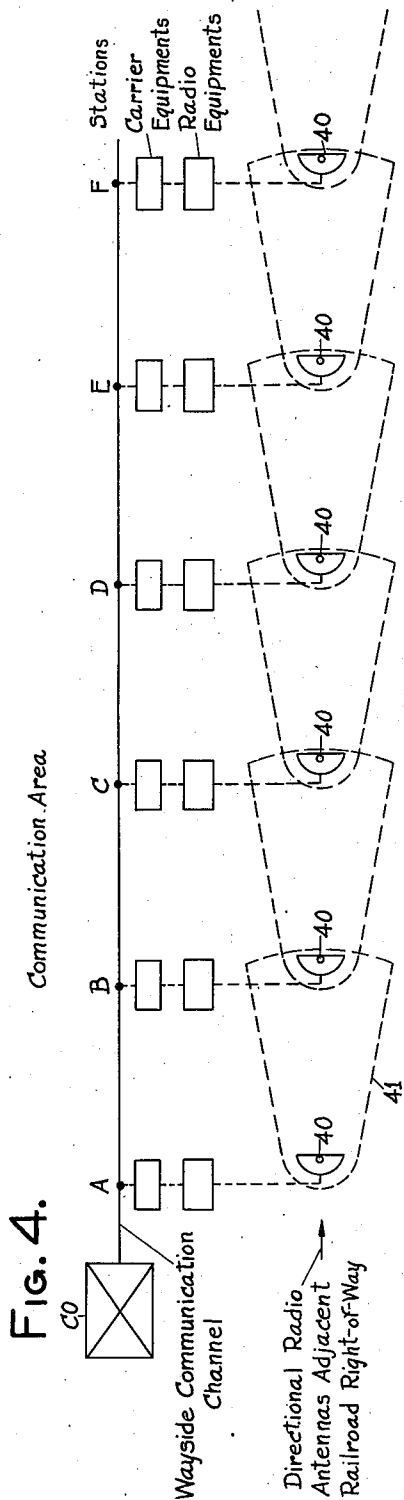
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UNITED STATES PATENT OFFICE

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SELECTIVE RADIO COMMUNICATION SYSTEM FOR A PLURALITY OF STATIONS

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Application June 19, 1945, Serial No. 600,359

16 Claims. (Cl. 250—6)

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This invention relates to train communication systems for railroads, and more particularly pertains to a system for providing communication to and from a plurality of trains and a central office, as well as providing communication between the several trains.

In a system involving communication to and from moving trains throughout an area under the direction of a central office, it is expedient to employ train carried radio transmitting and receiving equipments having an effective range much less than such area, and employ a plurality of wayside stations each with a similar effective radio range and coupled with the central office over a wayside communication channel for transmitting messages between the central office and each of the several trains in the area regardless of the limited range of the radio equipments. In such an organization, it will be apparent that the several wayside stations will include radio transmitting and receiving equipments also of a limited range comparable to the range of the various train equipments. The wayside communication channel interconnecting the central office with the various wayside stations may be of the wired current type, or any other suitable means for communicating messages between the central office and the several stations at the same time.

One problem involved in a communication organization of this type is, that when a given train is communicating with the central office, all other trains capable of likewise communicating with that office should know that such communication is occurring, so as not to break-in and interrupt the message then being transmitted over the wayside communication channel; and, since the train communicating equipment then transmitting may have an effective range sufficient to reach some particular way station but not sufficient to reach all train stations in the area, it is proposed to provide for the retransmission of the messages being received from any train station at a particular wayside station through the agency of the other wayside stations to all other trains within the area. This not only avoids interference with communication between any train and the central office, but also provides communication between trains not within effective range of each other through the agency of the wayside communication channel.

Generally speaking, and without any attempt to define the exact nature and scope of the present invention, it may be stated that the radio transmitting and receiving wayside equipment is

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disposed at locations or wayside stations spaced approximately the effective range of each wayside station radio equipment with a suitable overlap to take care of variations in actual operating range under different conditions. Thus, a train in any position between two adjacent locations or wayside stations is within communicating range with one or the other and perhaps both stations. Each wayside station preferably comprises a radio transmitter and a radio receiver associated with a directional antenna having such characteristics and operated in such a manner that the transmitter of one field station will have a relatively small effect upon the receiver of the adjacent field station for reasons which will appear hereinafter.

Each wayside radio receiver when supplied with a radio carrier frequency modulated with a particular distinctive tone which is characteristic of transmission from a train, acts to render its own radio transmitter inactive and repeat the message received over the wayside communication channel to all other wayside stations and the central office. The central office receives the message, and each of the other wayside stations cause their respective radio transmitters to retransmit such message to all other trains of the area. While a message is being received by the various trains in the area, either from a wayside station or direct from the transmitting train station, suitable means is operated so that the radio transmitters on such trains cannot be rendered active.

A predetermined distinctive tone is transmitted from each train station along with the voice message on its radio carrier frequency signal to condition the particular wayside station equipment which receives such radio carrier frequency signal for repeating such message over the wayside communication channel to the other wayside stations for retransmission purposes. As soon as such radio carrier frequency signal having the predetermined tone thereon ceases to be received by a wayside station, the repeat transmission over the wayside communication channel ceases. This organization is provided in order to avoid a sustained transmission of a carrier current over the wayside channel by reason of feed back action due to signal energy received by its associated radio receiver from the radio transmitter of an adjacent wayside station. Thus, when communication from a train stops, the predetermined tone frequency on its radio carrier frequency also stops, and conditions at the receiving wayside station for repeat transmission over the wayside communication channel will be cut-out or suppressed.

The directional radio antenna associated with the radio receiver and transmitter at each wayside station is employed to assure complete coverage of the area, and also to minimize the feed back action between adjacent stations causing erroneous or false retransmission conditions.

With such a directional arrangement in a retransmitting organization, it can be seen that a given train at any point on the railroad, when communicating with the central office, will cause such communication to exist on all of the other trains in the area, either by direct radiation for trains within radio range of each other or by retransmission of the message in case of trains which are out of radio range of each other. Without such directional control, it will be found that there are certain positions where a train might be within range of a particular wayside station, and yet not be within range of another train within the effective field pattern of such particular wayside station, with the result that there would be in effect a blind spot where said another train would not know of existing communication to the central office.

Thus, it may be said that one of the objects of the present invention is to provide a train communication system in which there is suitable means to prevent interference between trains in their communication with the central office, and also in such a way that there are no blind spots with respect to the intercommunication between trains both for advising of the busy condition of the wayside communication channel and also for the purpose of insuring intercommunication between trains.

Other objects, purposes and characteristic features of the present invention will be in part obvious from the accompanying drawings, and in part pointed out as the description of the invention progresses.

In describing the invention in detail, reference will be made to the accompanying drawings, in which like letter reference characters provided with distinctive preceding numerals, are used for designating corresponding parts throughout the several views, and in which:

Fig. 1 illustrates in a diagrammatic manner one organization of a central office provided with carrier current equipment for associating it with a carrier current communication channel between such central office and a plurality of wayside stations;

Fig. 2 illustrates diagrammatically a typical wayside station having carrier current equipments, associating it with the carrier current communication channel extending from the central office and also having its radio equipment for communication with the moving trains;

Fig. 3 illustrates in a diagrammatic manner the radio equipment employed at a typical train station;

Fig. 4 illustrates in graphical form one organization of the wayside communication channel and the various wayside stations with their directive radio antennas;

Fig. 5 illustrates in a graphical form a wayside communication channel interconnecting the wayside stations with the central office and with a modified arrangement of the directive radio antennas for the wayside stations; and

Fig. 6 illustrates in a graphical manner the effective range and direction of the radio equipment at a typical train station.

In order to simplify the illustrations in the

drawings and facilitate in the explanation of the fundamental characteristics of the invention, various parts and circuits have been shown diagrammatically in accordance with conventional symbols. Arrows with associated symbols (+) and (—) are employed to indicate connections of the circuits of the various relays to the opposite terminals of a suitable source of current for the energization of such relays; and the source of current may be of any suitable characteristic for the purpose intended. The various contacts of the relays involved in the illustrations are shown conventionally as being in a lower or inclined position when the coil or winding of the associated relay is deenergized, and in a raised or horizontal position when the relay is energized; the contacts belonging to any given relay are shown connected to its coil or winding by dotted lines, and these contacts may be either below or above the illustration of the relay winding. The front and back contacts between which the movable contacts are operated by the different relays are shown conventionally as arrow heads, and the movable contacts are ordinarily of the type which have their contacts pulled downwardly by gravity or by spring action.

The specific embodiment of the invention chosen for the purposes of illustration includes a carrier current wayside communication system sometimes termed wired radio, and this communication system or channel is of the conventional type for transmitting messages between the central office and the plurality of wayside stations. The carrier frequency employed for such wayside channel of communication may be of any suitable frequency employed for such purposes and may have its carrier frequency modulated in any suitable manner for the transmitting of voice messages.

Each of the wayside and train stations has a suitable radio transmitting and receiving equipment of the conventional type operating on a suitable carrier frequency selected for the particular use of the control area of the railroad under consideration; and in this connection it is contemplated that such frequency will ordinarily be in the megacycle band since the higher frequencies are more suitable to directional antenna control, although other frequencies may be employed. For the purposes of the present disclosure, frequency modulation of the radio carrier signals is assumed to be employed for reasons which will be explained as the description progresses, it should be understood that the characteristic principles of the present invention may also be applied to an organization employing amplitude or phase modulation.

Since the structure and operation of conventional radio transmitters and receivers are well understood in the art, as are also conventional carrier current transmitters and receivers, no attempt has been made to illustrate the various component parts in their entirety; and only those parts have been shown which have a direct bearing and relationship to the parts necessary for illustrating the characteristic features of the organization embodying the present invention. In other words, the various component parts of such an organization comprising oscillators, frequency multipliers, amplifiers, modulating and demodulating organizations, and the like, have been omitted for the sake of simplicity in the disclosure of the novel combination constituting the invention. Also, various detailed component

parts of the conventional units may be varied as desired without altering the operation of the organization as a whole. It is also assumed that the various sources of energization for supplying potential to the plate circuits, for biasing the vacuum tube grids, for effecting the energization of vacuum tube heaters, and the like, may be provided in any of the conventional and well known ways; and certain sources for the plate circuits have been shown only in those cases where it is believed expedient to indicate such sources as being selectively applied to better indicate the conditions under which the invention is intended to operate.

GENERAL ORGANIZATION

The extent of the communication area to which the present invention is applied may be determined in any desired manner depending upon the operating characteristics of the particular railroad involved. Such an area, for example may be a traffic dispatching division, a locomotive division, or any other arbitrary section of territory of the railroad throughout which communication is desired between a central office and the trains in that area. For convenience in the disclosure of the invention, it is assumed that the central communication office CO in Fig. 4 is connected with a plurality of the wayside stations A, B, C, D, etc. by a carrier current system. Such system involves the use of line wires, such as the line wires 1 and 2 extending throughout the control area as indicated in Figs. 1 and 2 when placed end to end. This line circuit may be used for various other services without interference with the carrier current system, or may be a line circuit used wholly for the wayside communication channel. In any event, the line circuit should be suitably terminated at each end so as to provide the proper electrical characteristics for such a system. Such a termination is indicated at 3 in Fig. 1.

The carrier current equipment at the central office CO (see Fig. 1) and at the various way stations A, B, C, D, etc. (see Fig. 2) is inductively connected to the line circuit through suitable coupling transformers 4 and blocking condensers 5, so as to suitably protect the carrier current equipments from the other services on the line circuit and also from lightning surges and the like.

Central office apparatus

Referring to Fig. 1, it will be noted that a suitable carrier current receiver is connected inductively through its line coupling transformer 4 and is normally rendered active by reason of the connection of its plate supply through back contact 6 of the transmit relay T. Thus, any carrier current signal imposed upon the line circuit will be received and the message modulating such carrier current signal will be reproduced by the associated loudspeaker. Associated with the carrier receiver is a suitable carrier responsive relay CR which is normally de-energized but is so related to the receiver that it is energized and picks up its contacts whenever a carrier current signal is received over the line circuit regardless of whether such signal is modulated with a message or not.

The central office also includes a carrier current transmitter inductively coupled to the line circuit through the line coupling transformer 4, and this carrier current transmitter is normally inactive. However, the carrier current trans-

mitter can be set into operation, provided no carrier signal is being received by its associated receiver as indicated by the indicator lamp BK, by merely actuating the self-restoring push button PB. More specifically, the actuation of the button PB closes the circuit for relay T from (+) and including back contact 7 of relay CR, push button PB in an actuated position, windings of relay T to (-). The picking up of the relay T opens back contact 6 to render the associated carrier current receiver inactive, and to close front contact 6 to render the carrier current transmitter active. With the carrier current transmitter active, speaking into the microphone will cause the transmission of a suitable message by the modulation of the carrier. It is, of course, apparent that the operator must hold the button PB actuated throughout the transmission of a message.

In the event that a message is being received, it is apparent that front contact 7 of the carrier responsive relay CR will be closed thus energizing the busy indicator BK so that the operator is advised against endeavouring to transmit a message. But in the event that he should inadvertently actuate the button PB, it cannot energize the relay T under such circumstances since the back contact 7 is open.

Typical wayside station apparatus

Each wayside station includes a suitable carrier current receiver inductively coupled to the line circuit through its line coupling transformer 4, and is normally rendered active by reason of the connection of its plate supply of energy through back contact 20 of tone responsive relay 2TR.

A suitable carrier responsive relay 2CR is connected to the associated carrier current receiver so as to be energized and pick up its contacts wherever a carrier current signal is received under the line circuit regardless of whether such signal is modulated with a message or not. The closure of front contact 21 of relay 2CR connects (+), through back contact 22 of the tone responsive relay 2TR to the transmit relay 2T thus causing the associated radio transmitter to be connected to its associated antenna through front contact 23 and to be rendered active by the connection of its plate supply through front contact 24. Since the carrier current receiver is directly connected to the radio transmitter through connection 25, any message received by the carrier current receiver is repeated by the associated radio transmitter.

Each wayside station includes a suitable radio receiver which is normally connected to the antenna through back contact 23 of relay 2T; and is normally rendered active for the reception of radio frequency signals modulated with any desired messages by reason of the fact that its plate supply is normally connected through back contact 24 of relay 2T. Associated with this radio receiver is a suitable band-pass filter 26 for passing the frequency of the tone carried by the radio frequency signals transmitted from any train station. For the purposes of definiteness in the disclosure this frequency is preferably of a super-sonic frequency such as 20 kilocycles, but may be of any suitable selected frequency. The output of the band-pass filter 26 is supplied to the tone responsive relay TR through a full wave rectifier unit 27.

Whenever the tone responsive relay 2TR is picked up due to the reception of a radio carrier

frequency signal having superimposed thereon the particular selected tone, the opening of back contact 22 prevents the inadvertent energization of relay 2T, while the opening of back contact 20 disconnects the plate supply from the carrier current receiver and connects it to the carrier current transmitter so as to render it active to repeat the messages received by the associated radio receiver. This repeater connection is indicated in the drawing of Fig. 2 by the wire 28, but it is to be understood that any suitable means required for repeating such messages may be employed, and especially is preferable that the output of the radio receiver include filter means for preventing the distinctive tone transmitted by the train stations from being repeated over the connection 28 to the associated carrier current transmitter.

The carrier current transmitter is of any conventional type and transmits suitable carrier current signals which are modulated in accordance with the messages received by the associated radio receiver. It is assumed that the carrier current transmitters and receivers at the central office and at each of the wayside stations operate on the same frequency; and similarly, it is also assumed that the radio transmitters and receivers at each of the wayside stations and the train stations also operate on the same radio frequency.

As will be noted by the legend associated with the antenna of Fig. 2, such antenna is intended to be of a suitable directional type giving an effective radio field as shown in Figs. 4 and 5. The directional features will be discussed in greater detail in connection with the discussion of the directional characteristics of the system of the present invention.

Typical train station

With reference to Fig. 3, a typical train station is illustrated each including a radio receiver and a radio transmitter both of the conventional type. The radio receiver has associated therewith a suitable loudspeaker and is normally rendered active for the reception of radio frequency signals by reason of the connection of its plate supply through back contact 30 of transmit relay 3T, and by reason of the connection of the antenna to such radio receiver through back contact 31 of transmit relay 3T.

Whenever the radio receiver receives a radio carrier frequency signal, the relay 3CR is caused to be energized picking up its front contact 32 and energizing the busy lamp 3BK. This carrier responsive relay 3CR picks up regardless of whether the carrier signal received is modulated with a message or not. The opening of back contact 32 prevents the operation of the self-restoring push button 3PB from energizing the transmit relay 3T. In this way, whenever the train station is receiving a radio carrier frequency signal, such a station is prevented from interrupting such reception even though the push-to-talk button 3PB is actuated. However, when no radio carrier frequency signal is being received, the actuation of the push-to-talk button 3PB closes a circuit including back contact 32 of relay 3CR to energize relay 3T which when picked up renders the associated radio receiver inactive and renders the associated transmitter active by the closure of front contact 30 to connect the plate supply to the radio transmitter and by the closure of front contact 31 connecting the directional antenna. In this connection, further description of directional characteristics of the antenna will

be considered in connection with the disclosures of Fig. 6.

Whenever the radio transmitter is rendered active, it has an associated tone generator which causes the radio carrier frequency signal to be modulated in accordance with such distinctive tone. This tone is impressed upon the radio frequency regardless of whether the operator is speaking into the associated microphone or not. The tone generator is preferably of the type which produces a supersonic tone that does not interfere with the efficient and proper communication of voice messages.

It is believed that the nature of the invention, its advantages and characteristic features can be best understood with further description being set forth from the standpoint of operation and functioning of the system.

OPERATION

Referring to Fig. 4, a graphic representation of the system organization shows a central office CO at the left hand end of a wayside communication channel represented by a single line as connecting the central office CO with a plurality of wayside stations A, B, C, D, E and F; but it is to be understood that the central office may be located at any point along the communication channel or at the right hand end. The wayside stations A, B, C, etc. are distributed throughout the communication area along the right-of-way of a railroad. This right-of-way probably will not be in a straight line, but will include curves of different degrees, but this is not material to the present invention, since each station has associated therewith a directional radio antenna 40 which has its field directed to cover that portion of the railroad right-of-way extending to the next adjacent wayside station.

These directional radio antennas 40 may be of any suitable type using corner reflectors, parabolic reflectors, or similar reflectors. On the other hand, if it appears advantageous antenna arrays may be employed. The particular manner in which the antennas 40 are made directional is not material to the practice of the present invention; but it is to be understood that the particular means employed must provide a substantial ratio of directivity so that the major portion of the radiation of the antenna will extend toward the next adjacent station. Such ratio of directivity may be in the order of one hundred to one, or it may even be more efficient under certain circumstances.

In Fig. 4, the field patterns of the antennas 40 are indicated by dotted lines 41 which represent the points of equal radio field or signal strength with respect to their respective antennas. These field representations 41 have not been drawn to show the actual characteristics of some particular type of antenna but have been drawn merely to show that antenna beams its radiations in a particular general direction and with an overlap with respect to the next adjacent station. In this way, the railroad right-of-way is adequately covered with a beam of radio frequency signal throughout its length whenever all of the stations are rendered active for the transmission of a message at the same time.

With the effective radio field of each antenna overlapping with the effective radio field of the next adjacent station, it will be apparent that there will be a point in the overlapping portions of the fields which will represent equal field intensities of both stations. The particular location

of this point of equal field intensity is probably not the same from time to time due to the various electrical phenomena characteristic to changes in atmospheric conditions; but in any event with the proper spacing of stations and selection of field strengths for the various stations, it will be possible to obtain a change from the point of equal field intensity to a point where the closest station predominates by a substantial percentage within a relatively short distance. The distance between the two points at which one signal is twice as strong as the other located on opposite sides of the equal strength signal point, may be conveniently termed the "fringe zone" of reception for reasons presently to be explained.

It is well understood that a radio receiver of the frequency modulation type is capable of maintaining reception of that station which has the highest signal strength to the exclusion of other stations of lesser strength on the same carrier frequency channel. In other words, when two stations operating on the same frequency are received at the same time by a receiver, that station which has the higher signal strength is the one which is received in preference to the other. This selectivity characteristic usually operates to a marked degree whenever the signal strength for the two transmitting stations is of a ratio of two to one, but will still be somewhat effective upon even smaller ratios. Thus, it will be appreciated that the passage of a train station from the effective radio field of one wayside station to another will receive one station in preference to the other on each side of the point of equal intensity of the two stations. This selectivity of reception is maintained except in passing through the point of equal radio signal intensities, where there is little or no selectivity between the signals. Under such conditions of reception, there are two types of interference in receiving when two transmitting stations are using the same frequency channel.

One type of interference is termed cross-talk, where the voice modulations of both signals are reproduced. This type of radio interference will not be objectionable in the present invention, since both stations transmit the same voice message and the two modulations of the two different signals will combine to give a single audio reproduction because there will be no substantial time lag in the retransmission operation.

Another type of interference present in receiving two substantially equal radio signals on the same frequency channel involves the production of a beat note in accordance with the difference in the instantaneous frequency deviation of the two carrier signals. When the frequency swings of the beat note are large, this beat note condition is not audible. Thus, this type of interference will have substantially no adverse effect on the reception of messages in the present organization, because all stations are operating on the same basic frequency to transmit the same message. In other words, the frequency deviation can be kept small between any two adjacent stations by maintaining the basic frequency of the transmitters fairly constant and substantially the same, which taken in connection with the fact that the modulating audio frequencies cause variations in carrier frequency of the two signals to substantially the same extent for both stations because of the identity of the message, will cause the instantaneous frequency deviation for the two carrier signals to remain small. This of course maintains the frequency swing of the beat

note condition rather large, so that it will not interfere with the reception of a message, even though such message is being received from two stations simultaneously. Thus, for all practical purposes the passage of a train station from the effective range of radio field of one wayside station into the effective range or radio field of another wayside station will not be detectable in the continuity of message reception.

In this connection, it should be noted that the directional radio antennas for the wayside stations are all directing their radio beams in the same direction to provide minimum length fringe zones in the overlapping portions of the wayside station ranges. The reason for this is because the present invention takes advantage of the characteristics of attenuation of radio signals. For practical purposes the attenuation of a radio signal may be considered as varying inversely with the cube of the distance away from the transmitter. Thus, the forward signal of a wayside station produces an attenuation curve of signal strength having a rather steep slope near the station which drops off to a rather flat portion as the signal approaches zero at a distance from the station. This is of course also true with respect to the relatively small back-signal in the rear of the directional antenna. In considering two adjacent stations, it will be appreciated that the back-signal curve is shorter than the forward-signal curve, and that the forward-signal curve at its rather flat portion will cross the back-signal curve at a rather steep portion so that the "fringe zone" is relatively short compared to what it would be if directional antennas were not employed. It should also be noted that this fringe zone is reduced to substantially zero the more nearly perfect the directivity of the antenna. Thus, the present invention not only obviates the difficulties involved in using a common frequency channel for plurality of radio stations but also organizes the arrangement of stations to minimize the conditions under which adverse conditions originate.

For the above reasons, the railroad right-of-way is adequately covered with a field of radio signal so that a train station will receive a radio frequency signal regardless of its location on the railroad, and will receive a suitable signal for continuous reception of a message in passing over the railroad in either direction when all wayside stations are transmitting.

The train station antenna is arranged to have its effective field directed both in advance of the train and to the rear of the train as indicated in Fig. 6 of the accompanying drawings, so that the direction of train movement does not affect reception. The effective ranges or radio fields of the train station are indicated by the dotted lines, and the extent of each range substantially corresponds to the range of the wayside stations of Figs. 4 and 5. It should be understood that the train stations may have omni-directional antennas, but since a train is always traveling along the right-of-way in one direction or the other, it is only necessary that such train station receive signals either from the rear or in advance. For this reason, the efficiency of the train station antennas may be increased by making them directional in some suitable manner, such as explained for the wayside antennas.

Central office transmits to trains

Let us assume that the operator in the central office actuates the push-to-talk button PB and

energizes the transmit relay T (see Fig. 1). This renders the associated carrier current active, so that when the operator speaks into the associated microphone, the carrier current signal is modulated in accordance with the frequency of the voice message. This modulated carrier current is transmitted over the wayside communication channel to each of the wayside stations A, B, C, D, E and F shown in Fig. 4, which wayside stations are typically illustrated in Fig. 2.

The reception of the modulated carrier current at each wayside station causes its associated carrier current receiver to effect the energization of its carrier responsive relay, such as relay 2T. Thus, at each wayside station the associated radio transmitter is rendered active, and the radio frequency signal radiated from the directional antenna of such station is modulated in accordance with the audio modulations received by the associated carrier current receiver over the wayside communication connection between stations.

Since each wayside station of the communication area transmits the message originating at the central office, such message will be received at each train station in the communication area regardless of its particular location. Referring to Fig. 3 as a typical example, such train station will receive a radio carrier frequency signal modulated in accordance with the message, and this message will be reproduced by the associated loudspeaker. At the same time, the presence of the radio carrier frequency signal will effect the energization of the associated carrier responsive relay, such as relay 3CR, and effect the energization of the associated busy indicator such as lamp 3BK, while at the same time rendering the associated push-to-talk button such as button 3PB ineffective. Because this action takes place at all the train stations, they are locked-out, so to speak, and cannot interrupt the message being transmitted from the central office.

For the reasons explained above, each train station will continue to receive its message regardless of its location, and as it moves along the railroad right-of-way from the effective radio field of one wayside station into the effective radio field of a different wayside station.

A train transmits to central office

Let us assume that a train station is located within the effective range of a particular wayside station, such as station B for example of Fig. 4, but not within range of station C. When this train station actuates the push-to-talk button 3PB, the associated radio transmitter is rendered active and the radio carrier frequency signal radiated from such train station is modulated both with the distinctive tone created by its associated tone generator, and also by the frequency of the voice message spoken into the associated microphone. This radiated radio carrier frequency signal is received by the wayside station B, and referring to Fig. 2, it will be appreciated that the radio receiver at such wayside station effects the energization of its tone responsive relay 2TR which in turn renders the associated carrier current transmitter active so that the connection 28 will cause such carrier current transmitter to repeat the voice message received. The carrier current signal imposed upon the line wires 1 and 2, conveniently termed the wayside communication channel, is transmitted to the central office CO and to each of the other wayside stations A, C, D, E and F. At the central office the reception of the carrier current signal

results in the reproduction in the associated loudspeaker of the message transmitted by the train.

At each of the other wayside stations, the radio receivers have failed to receive the radio carrier frequency signal from the train station then transmitting because they are not within the effective range of such train station. Thus, the reception of the carrier current signal at such stations, results in the energization of the associated carrier responsive relay, such as relay 2CR, which in turn renders active the associated radio transmitter by energizing the associated transmit relay. Thus, the message modulating the carrier current signal is repeated through the connection 25 and causes the associated radio transmitter to transmit the same message. Thus, all of the wayside stations, except the station B, retransmit the message originally transmitted from a train station within the effective range of station B. It will be apparent that any train within the range of the wayside station B, will also be within range of the transmitting train station, so that it will receive the message direct, while each train out of the range of such transmitting train station, but within range of some particular wayside station, will receive the message from such particular wayside station. The reception of a radio carrier frequency signal at any train station, regardless of whether the message originates at the central office or some other train station, effects the picking up of its associated carrier responsive relay, such as relay 3CR, so that such train station cannot initiate operation of its associated radio transmitter, and thus cannot interrupt the communication of any particular train station with the central office, nor the communication between the central office and all train stations in the area.

In this connection, it should be noted that the transmit relay at each wayside station, such as relay 2T of Fig. 2 when energized by the reception of a carrier current signal, renders the associated radio receiver inactive, so that if some train station should fail to properly receive a radio carrier frequency signal and should endeavour to transmit to a wayside station, such erroneous transmission could not be received and effect the interruption of the message already on the wayside communication channel. In other words, there is an effective interlock at the wayside stations preventing interruption of a message being transmitted over the wayside communication channel, even though the other train stations are not actually prevented from transmitting. However, under normal operation of the system it is contemplated that the interlock will be extended to the various train stations in such a way as to indicate to such stations that they cannot transmit because the wayside communication channel is busy.

It is contemplated that a train station will generally initiate transmission while within range of only a single wayside station, and while carrying on its transmission will proceed within the range of that station and perhaps enter the range of another wayside station. Since the ranges of the adjacent stations overlap, the wayside station initially receiving a carrier frequency signal from a train station will continue to receive that signal and repeat the message onto the wayside communication channel, so that the station into the range of which the train station has just entered will continue to retransmit the message until the wayside station initially receiving the message has become out of range of the train station. Thus,

should a message from the train station continue even after wholly leaving the range of the receiving wayside station, the wayside station now including the train station then begins to receive the train station radio frequency carrier signal and repeat the message into the wayside communication channel, there being but a slight interruption of the message such as involving the drop away times of a tone responsive relay TR and a carrier relay CR together with the pick up of a tone responsive relay at the station next to transmit. Such an interruption or lapse of time would of course hardly be appreciable since such relays operate in fractions of a second.

Referring to the illustration of Fig. 4, it should be appreciated that the wayside station ranges or radio fields have not been drawn to scale, so that it may be well to point out that the overlapping portion between the radio fields of two adjacent stations is a relatively short distance compared to the distance between stations. For this reason, it is contemplated that a train station will ordinarily initiate its transmission while within range of only a single wayside station, but it may happen that a train station will initiate transmission while within range of two wayside stations. In such an event, both wayside stations receive the message and act to repeat it onto the wayside communication channel. However, this causes no adverse effect in the transmission of the message to the central office, since the carrier current transmitters operate on the same basic frequency and may be of the type which have oscillators of the lock-in type tending to maintain the same frequency of the carrier current at both stations and thus cause a proper transmission of the message to the central office because both stations are transmitting the same message.

When all of the wayside stations are transmitting in the case where the message originates at the central office, it will be apparent that the radio receivers at all stations are rendered inactive because of the energized conditions of the transmit relays at such stations (see Fig. 2). Under the conditions where a train station is transmitting to a particular wayside station and the other wayside stations are retransmitting the message, it will be apparent that the reason why the wayside station receives the radio carrier frequency signal from the train station for preference to the wayside station to the left is because the wayside stations are provided with the directional antennas 40. In other words, it is contemplated that the directional antennas 40 are not affected by transmission of radio carrier frequency signals from the station next in the rear of such directional antenna in spite of the fact that its effective radio field overlaps with such station.

However, under the conditions where a particular wayside station is receiving from a train station and the other wayside stations are retransmitting the message, it might be possible due to radio reflections or the like, that upon the cessation of the transmission from the train station to the particular wayside station then receiving there might be sufficient hangover transmission from some wayside stations as to be received by such particular wayside station. The hangover transmission after the cessation of a train station is due to the resonant circuits employed and the time delay in relay operations, but such hangover transmission would occur for only a few micro-seconds. If such hangover transmission should be received by a wayside sta-

tion just having received a message from a train station, there would be what might be termed a feed back condition through the medium of the wayside communication channel if it were not for the provision of the present invention.

This is prevented in accordance with the present invention since a wayside station cannot repeat a message into the wayside communication channel unless the received radio carrier signal is accompanied by a particular distinctive tone. Thus, any feed back action is obviated in accordance with the present invention.

Referring to Fig. 5 of the accompanying drawings a rearrangement of the wayside stations within the communication area has been shown. It will be seen that the directional antenna 50 of the wayside station A is transmitting its beam toward the right while the directional antenna 51 of the wayside station B is transmitting its beam toward the left. Thus, the two beams may meet at a point 52 representing equal signal intensities.

The radio beams from antennas 50 at 51 are indicated by the dotted lines 53 and 54 respectively. Although the extent of range of such radio stations has not been shown, it is intended that the ranges of these stations will be substantially the same as shown in connection with Fig. 4 and of course comparable to the range of the train stations, as indicated in Fig. 6.

It will be apparent that this arrangement of directional antennas shown in Fig. 5, also provides complete coverage of the railroad right-of-way with a radio field when all of the wayside stations are transmitting a message originating from the central office CO. The traveling of a train from the range of station A to the range of station B will of course cause such train station to pass through what has conveniently been termed a fringe zone of signal intensities and including an intermediate portion in which the signals from stations A and B for example will be of equal intensity and contribute towards the reception of the message from the central office CO for reasons described above in connection with the consideration of Fig. 4. It should also be pointed out that similar conditions exist between the back-signals of two adjacent antennas, such as antennas 51 and 55 of stations B and C. In any event, when transmission is taking place with the message originating in the central office, all train stations within the communication area receive the message substantially continuously without interruption as the trains pass from the effective radio fields or ranges of successive stations along the railroad right-of-way. When all of the wayside stations are transmitting a message originating in the central office, no train station can initiate a message because its transmit relay cannot be energized by the push-to-talk button 3PB when the carrier responsive relay 3CR is picked up (see Fig. 3).

The only difference in this Fig. 5 is the rearrangement of the directional antennas of alternate stations and the spacing of the wayside stations. Thus, the characteristic features of the wayside stations and the train stations are the same as described in connection with the preceding Fig. 4. More particularly, while a train station is transmitting to some wayside station, every other train station is prevented from initiating transmission, since such other train stations either receive the message direct from the train station transmitting, or by the way of retransmission of the message through the wayside

communication channel, as explained in connection with Fig. 4.

More specifically, when a train station transmits within the range of station A for example (see Fig. 5), the message is received at station A and repeated into the wayside communication channel which results in the retransmission of such message from all of the remaining wayside stations B, C, D, E and F. Thus, a train station may communicate with the central office as well as with all train stations within the communication area. In the event that a train station initiates its transmission within the overlapping portion of the effective fields of two adjacent wayside stations, such as wayside station A and B, both wayside stations will receive the train transmitted radio signal and repeat its message into the wayside communication channel in the same manner as explained in connection with Fig. 4, since the carrier current apparatus is considered to be of the type having the same frequency characteristics, and may have oscillators which lock-into synchronism with each other. This results in the reception of the message at the central office and the retransmission of the message from the other wayside stations.

When a train initiates transmission of a message while within the range of one wayside station, such as wayside station A, and then moves into range of wayside station B, the wayside station B continues its retransmission until the train has moved out of range of the wayside station A, since the retransmission operation at station B prevents any reception of a radio frequency carrier signal at that station. A similar action occurs should a train station initiate transmission within the range of wayside station B and then travel into the range of wayside station C. It is thus apparent that a train station may communicate with the central office or any other train station without any substantial interruption as it proceeds along the railroad right-of-way.

In this Fig. 5 organization of the wayside stations within the communication area, it will be apparent that should a train station be transmitting to station A for example, the retransmission of such message from the station B is directed toward the station A. But since the train station is closer to the wayside station A than is the wayside station B, its radio carrier frequency signal will be the stronger and will be received by wayside station A in preference to the signal from wayside station B. This is of course due to the characteristics of a frequency modulation type of radio receiver as previously discussed. Upon the cessation of the transmission from the train station, the station B might continue its transmission of a radio carrier frequency signal for a few micro-seconds, or what may be termed a hangover time, due to the characteristics of oscillatory or tuned circuits and the release time of certain relays. If such hangover radiation should be received by the station A, it would cause the wayside communication channel to maintain wayside station B active which would cause a continued circulatory feed-back action between the stations A and B, for example. Such a feed-back condition cannot occur in connection with the present invention, since the presence of a distinctive tone is required upon the reception of a radio signal in order for the repeat operation of a wayside station to take place. For this reason, the cessation of transmission of a radio carrier frequency signal from a train station immediately renders the associated wayside station then re-

ceiving ineffective for reception from any other source not transmitting the distinctive tone.

Thus, the present invention provides a communication system between trains and at a central office as well as between the trains themselves although out of range with each other, through the medium of what has conveniently been termed retransmission of the train message. The present invention has been more particularly described as a communication system used in connection with railroads for transmitting messages between trains and the like, but it is to be understood that the invention may be adaptable for other uses such as in a communication system for automobile traffic along highways, or in a communication system for air traffic over the airways of an area.

Having described a communication system and the various characteristic features thereof as embodying the present invention, it is desired to be understood that this form is selected to facilitate in the disclosure of the invention rather than to limit the number of forms which it may assume; and, it is to be further understood that various modifications, adaptations and alterations may be made to the specific form shown to meet the requirements of practice, without in any manner departing from the spirit or scope of the present invention.

What I claim is:

1. In a two-way train communication system of the space radiation type for railroads providing for communication to and from a central office and any one of a number of trains in a communication area, said system comprising, radio transmitting and receiving means on each train manually controllable only if no signal is being received to send out a carrier frequency modulated with a message and also a predetermined tone frequency, a plurality of way stations each including a transmitter and receiver and spaced along the railroad to be within range of a train in any location in the communication area, means including a communication connection between said way stations and responsive to the reception from a train on the carrier frequency modulated with said predetermined tone frequency at any given way station for rendering the transmitters for all other way stations effective to send out a signal to all other trains, thereby preventing manual control of the radio transmitters on such other trains to cause transmission and interfere with the transmission of such message.

2. In a system of communication between a central office and a plurality of mobile units traveling through a communication area, a plurality of wayside stations in the communication area each provided with a radio receiver and a carrier current wayside transmitter, means constituting a communication channel between said way stations and said central office for effecting the transmission of a carrier current signal in response to a message received at any way station and repeated by its wayside carrier current transmitter as received by its associated radio receiver, a radio transmitter on each mobile unit having a limited range less than the extent of the communication area but effective to transmit messages to the radio receiver of the nearest wayside station, and means associated with each wayside station responsive to the reception of a carrier current signal received over the wayside communication channel from some other wayside station for preventing any mobile unit

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from transmitting to that way station, whereby the initiation of communication with the central office by any mobile unit via a particular way station in the communication area prevents break-in by any other mobile units within range of the other way stations.

3. In a system of communication between a central office and a plurality of mobile units traveling through a communication area, a plurality of wayside stations distributed throughout said communication area, means constituting a communication channel between said wayside stations and said central office and between each wayside station and every other wayside station, equipment at each wayside station capable of receiving radio messages and repeating such messages over said wayside communication channel to the control office and each of the other stations, a plurality of mobile units each provided with radio transmitting equipment of a limited range less than the extent of the communication area but of sufficient range to always reach the nearest wayside station, and means at each wayside station responsive to a message on said wayside communication channel to prevent its associated equipment from receiving radio messages for repeat transmission over said wayside communication channel, whereby any mobile unit can communicate with the central office over the wayside communication channel without interference from other mobile units within range of other wayside stations.

4. In a system of communication between a central office and a plurality of mobile units traveling through a selected area, a plurality of wayside stations distributed through said area and each having a radio transmitter of limited range operable to radiate a directional radio beam to cover the distance between it and the next adjacent station in one direction but not the other, said radio transmitters being of the frequency modulation type and all such transmitters being operable on the same radio frequency channel, a wayside communication system for transmitting a message from the central office to all wayside stations and acting at such stations to cause the radio transmitters to repeat such message, and a plurality of mobile units each provided with a radio receiver of the frequency modulation type having means adapted to selectively receive the stronger of two radio signals, whereby each mobile unit can receive a message from said central office without substantial interruption as it travels into and out of range with the successive wayside station.

5. In a system of communication between a plurality of mobile units traveling through a communication area, a plurality of wayside stations distributed through said communication area, radio transmitting and receiving equipment at each wayside station having a directional antenna for directing its field of radiation and response toward the next adjacent station in one direction but not the other, and each station having an effective range extending to at least the next adjacent station in said one direction, a plurality of mobile units each provided with radio transmitting and receiving equipment of limited range corresponding to said wayside stations whereby each mobile unit is always within range of at least one wayside station regardless of its position in the area, and a wayside communication channel connecting said wayside stations for repeating any message received by the radio receiving equipment at any given way-

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side station from a mobile unit within its range to cause the radio transmitting equipment at the remaining wayside stations to retransmit such message for communication to the mobile units within range of the respective wayside stations, whereby each mobile unit can communicate with every other mobile unit in the area regardless of its limited range.

6. In a system of communication between a plurality of mobile units traveling through a communication area, a plurality of wayside stations distributed through said area, radio transmitting and receiving equipment at each wayside station, said radio equipment having a limited effective range but which is sufficient to cover the distance from its station to the effective range of the next adjacent station, whereby a mobile unit is always within range of at least one wayside station regardless of its position in the area, a plurality of mobile units each provided with radio transmitting and receiving equipment having an effective range of a limited distance corresponding to the effective range of the wayside stations, means associated with each mobile unit for causing the transmission from such unit to be modulated in accordance with the distinctive tone in addition to any voice message transmitted from the mobile unit, a communication channel interconnecting said wayside stations, means at each wayside station for repeating the message received by the radio receiving equipment at that station over said wayside communication channel to the other wayside station only providing said radio receiving equipment at such given station receives a radio signal modulated by said distinctive tone, and means at each wayside station responsive to a message on the wayside communication channel for causing its associated radio transmitting equipment at that station to retransmit the message received over said wayside communication channel, whereby, the cessation of reception at any particular station from a mobile unit causes the cessation of the repeat action of the associated radio receiver upon the wayside communication channel to thereby prevent any retransmitted radio signal from being received by an adjacent station when a mobile unit ceases transmission.

7. In a system of communication between a plurality of mobile units and a central office, a plurality of wayside stations distributed through a communication area, radio transmitting and receiving equipment at each wayside station having a directional antenna for directing its field of radiations and responses toward the next adjacent station, all of said antennas directing their beams in the same general direction and effective to extend their beams to at least the next adjacent station in said direction, a plurality of mobile units each provided with radio transmitting and receiving equipment of limited range, and a wayside communication connection extending between said wayside stations for repeating the message received by the radio receiving equipment at any given station to the wayside radio transmitting equipments at all other stations for retransmitting such message, whereby each mobile unit may communicate with other mobile units in the communication area which may be out of range of its own radio transmitting equipment.

8. In a radio communication system for railroads, radio equipment on each of a number of trains including transmitting and receiving means operating on the same carrier frequency,

said equipments being normally in condition to receive and being manually controllable to transmit provided said carrier frequency is not being received from some other source, and radio equipment at a way station along the railroad including transmitting and receiving means operating on the same said carrier frequency and manually operable to transmit only if no carrier frequency is being received from a train, said way station equipment including a directional antenna for providing transmission and reception substantially in one direction only along the railroad, whereby all trains within range of said way station are within range of each other so that any train communicating with said way station locks out all other trains within range of said way station.

9. In a radio train communication system for railroads, a plurality of train carried equipments each including radio transmitting and receiving means of limited range operating on the same carrier frequency and manually operable to transmit only if no carrier frequency is being received from some other source, a plurality of way stations spaced along the railroad at distances conforming with the range of said train carried equipments, said way stations having radio transmitting and receiving means operating on the same said carrier frequency, said way stations also having directional antennas for providing transmission and reception substantially in one direction only along the railroad.

10. In a train communication system for railroads, a number of train carried equipments each including radio transmitting and receiving means of limited range operating on the same carrier frequency and manually controllable to transmit only if no carrier frequency is being received from some other source, a plurality of way stations spaced along the railroad at intervals conforming with the range of said train carried equipment, said way stations having radio transmitting and receiving means operating on the same said carrier frequency and uni-directional antennas directed in the same direction, means constituting a communication channel connecting all of said way stations and a central office, and means operating over said communication channel for causing all of said way stations to transmit carrier frequency when any way station is receiving a carrier frequency from the transmitting means on a train.

11. In a train communication system for railroads, radio equipment on each of a number of mobile units including transmitting and receiving means of a limited range operating on the same carrier frequency and manually operable to transmit only if no carrier frequency is being received, a plurality of way stations spaced along the railroad at intervals corresponding with the range of said mobile unit equipments, said way stations having radio transmitting and receiving means operating on the same said carrier frequency and uni-directional antennas directed in the same direction, a line circuit connecting all of said way stations with a central office, a carrier current transmitter and a receiver at the control office and at each way station operated by carrier current on said line circuit, the radio receiver means and carrier current receiver at each way station being normally in condition to receive and the radio transmitting means and carrier current transmitter being normally inactive, means associated with the radio receiving means at each way station for rendering the

carrier current transmitter active, and means associated with the carrier current receiver at each way station for rendering the radio transmitter active.

12. In a communication system for railroads providing communication from any one of a number of trains to any one of a plurality of way stations and a central office, radio equipment on each train including radio transmitting and receiving means of limited range operating on the same carrier frequency and manually operable only if no carrier frequency is being received from some other source to transmit an inaudible control tone along with a voice message, a plurality of way stations spaced along the railroad at intervals corresponding with the range of said train carried equipments, each of said way stations including radio transmitting and receiving means operating on the same said carrier frequency, means constituting a communication channel between all of said way stations and a central office, and means at each way station responsive only to the reception of said control tone from a train for rendering the radio receiving means at that station effective to send voice messages over said communication channel to said central office.

13. In a train communication system for railroads, radio equipment on each of a plurality of trains including transmitting means and receiving means operated on the same carrier frequency and manually controllable to transmit only if no carrier frequency is being received, a plurality of way stations spaced along the railroad at intervals corresponding with the range of said train equipments, each of said way stations having a radio transmitting and receiving means operating on the same said carrier frequency, means constituting a communication channel for voice messages between all of said way stations and a central office, means at each way station for transmitting over said communication channel any voice message received by its respective radio receiving means, and means at each way station responsive to a voice message over said communication channel for rendering the associated radio transmitting means active to transmit a carrier frequency, whereby trains beyond the range of any given train communicating with the central office are prevented from breaking in by reason of the retransmission from all other way stations when a given way station is receiving a voice message from a train.

14. In a system providing two way communication between a central office and a plurality of trains within a communication area, a central office, a plurality of way stations in a communication area along a railroad track each including a single channel radio transmitter and receiver, means constituting a communication connection operative over a wayside channel between each of said way stations and said central office for permitting the transmission to the central office of a message received at any way station or the transmission of a message from the central office to any way station, equipment on each train in the communication area including a single channel radio transmitting and receiving means operable on the same single channel as the way stations and having a limited range less than the extent of the communication area, manually operable means on each train for rendering the associated transmitting means effective to send out a radio signal, means at each way station acting in response to a radio signal

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transmitted from a train from within range of that station to transmit a message over said communication connection for rendering all of the other way stations effective to transmit radio signals to all trains within their range, whereby the starting of communication with the central office by any particular train in the communication area causes all other way stations to send radio signals reaching all trains in the communication area out of range of that particular train.

15. In a communication system providing two way communication between a central office and a plurality of trains within a communication area, a central office, a plurality of spaced way stations located throughout the communication area each including radio transmitting and receiving equipments having a limited range of directional characteristics but so spaced that their ranges are overlapped to provide a complete coverage of the communication area, a wayside two-way communication channel for communicating between the central office and each of the way stations, means at each way station responsive to a message over said communication channel from said office or an associated way station to cause its associated radio transmitter to be effective to transmit such message to thereby communicate with the trains within its range, and means at each way station responsive to the reception of a radio message by its associated radio receiver for rendering its associated transmitter ineffective and acting to transmit such message over said communication channel to said central office and each of the other stations, whereby the transmission from a particular train station to a particular way station effects the retransmission of that message from all other way stations so that the trains within the ranges of such other stations can receive the message but with respect to the trains within range of the way station at which its transmitting means is rendered ineffective such trains receive the message directly from the train station then transmitting.

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16. In a system of communication between a plurality of mobile units travelling through a communication area, a plurality of wayside stations distributed through said communication area, radio transmitting and receiving equipment at each way station operable on a particular frequency and having a directional antennae for directing its field of radiation and pickup toward the next adjacent station in one direction but not the other, and each station having an effective range extending at least to the next adjacent station in said one direction, a plurality of mobile units each provided with a radio transmitting and receiving equipment operable on said particular frequency and of a limited range corresponding to the range of said wayside stations, whereby each mobile unit is always within range of at least one wayside station regardless of its position in the area, and a wayside communication channel connecting said wayside stations for repeating any message received by the radio receiving equipment at any given wayside station from a mobile unit within its range to cause the radio transmitting equipments at the remaining wayside stations to retransmit such message to the mobile units within range of their respective wayside stations, whereby each mobile unit can communicate with every other mobile unit in the area regardless of its limited range.

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