April 16, 1946. W. S. HALSTEAD 2,398,741

SIGNALING SYSTEM

Filed Sept. 16, 1944 6 Sheets-Sheet 1

FIG. 1

WILLIAM S. HALSTEAD
INVENTOR

ATTORNEY

April 16, 1946. W. S. HALSTEAD 2,398,741

SIGNALING SYSTEM

Filed Sept. 16, 1944 6 Sheets-Sheet 2

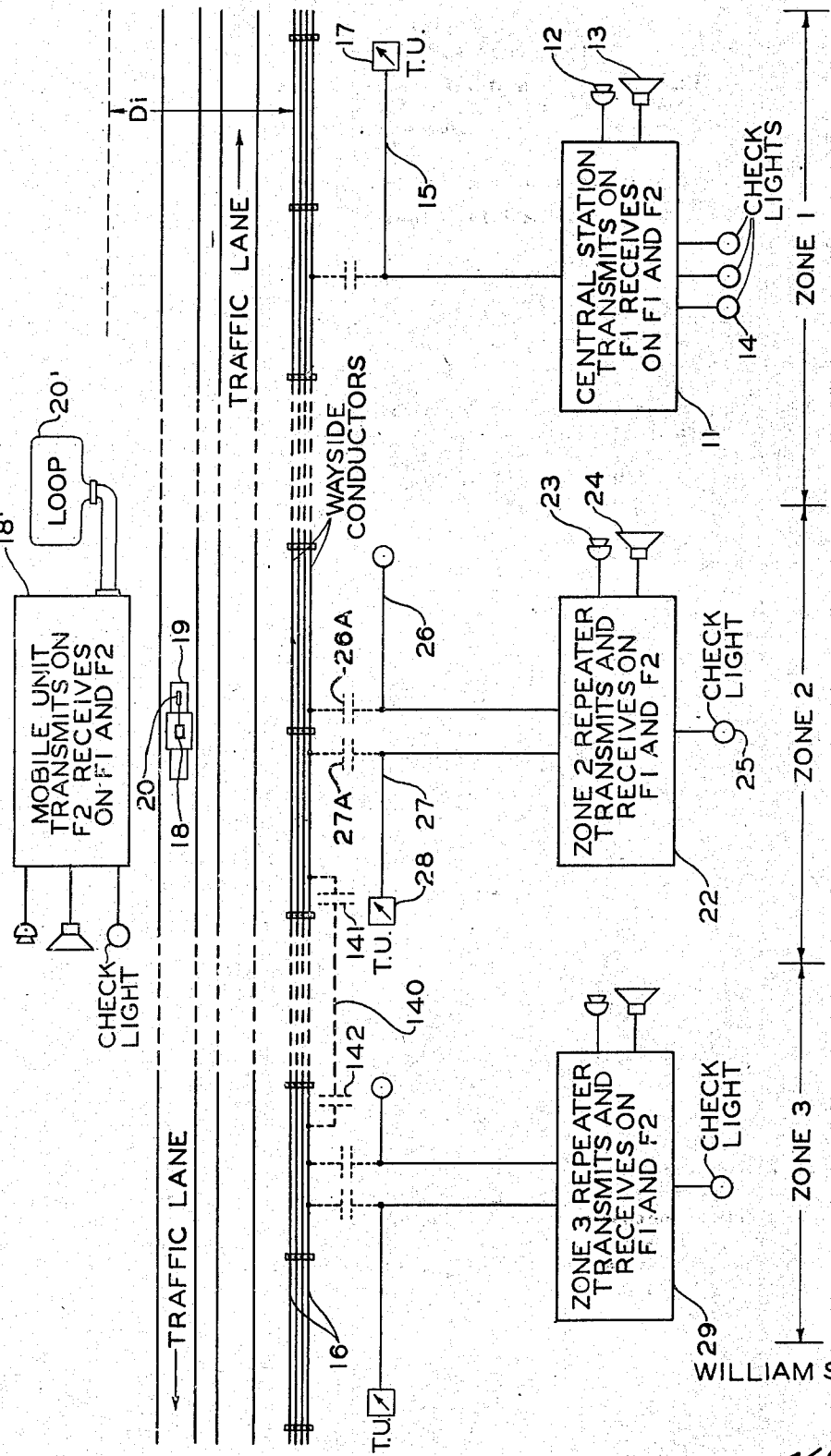


FIG. 2

WILLIAM S. HALSTEAD
INVENTOR

ATTORNEY

April 16, 1946. W. S. HALSTEAD 2,398,741

SIGNALING SYSTEM

Filed Sept. 16, 1944 6 Sheets-Sheet 3

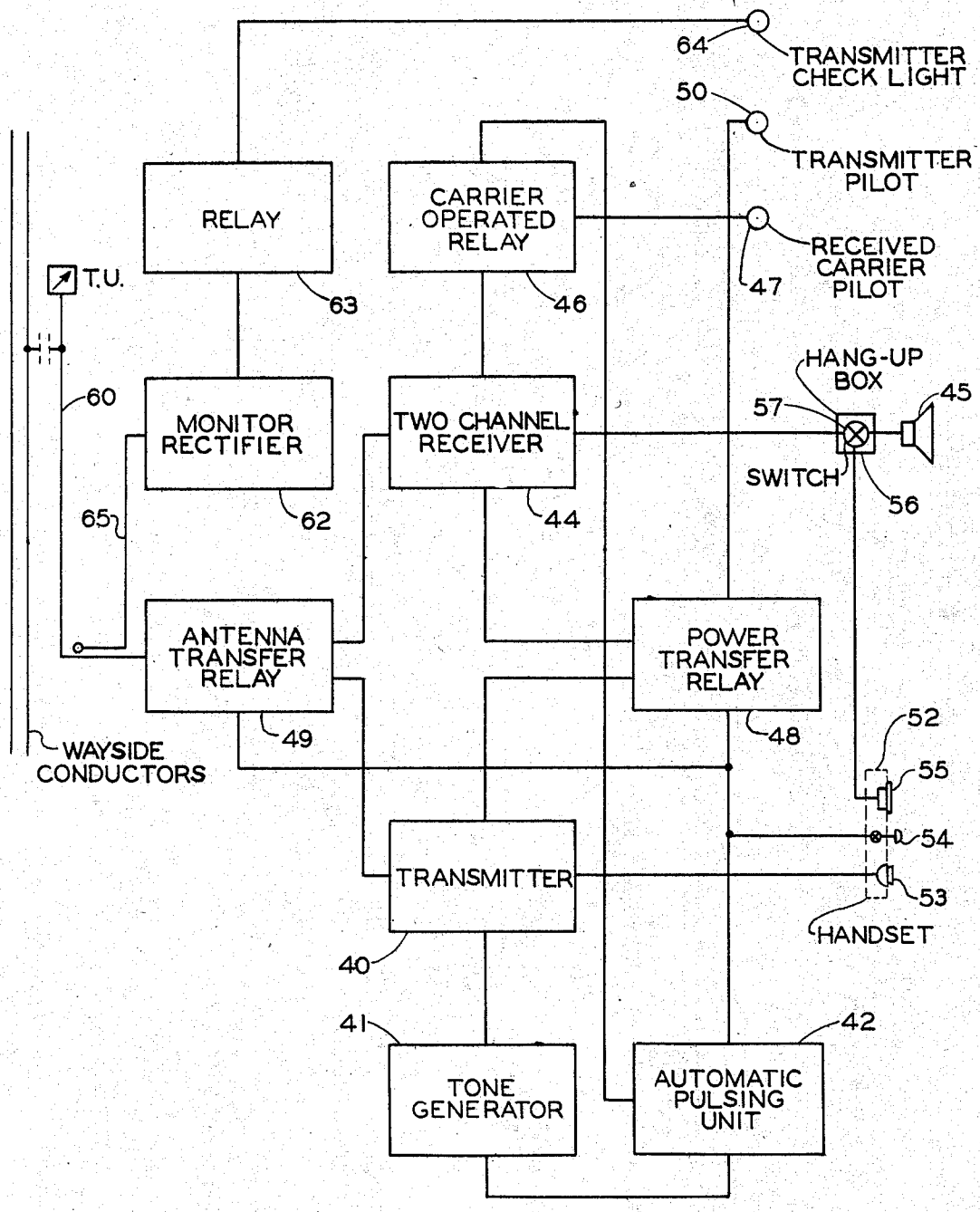


FIG. 3

CENTRAL STATION UNIT

WILLIAM S. HALSTEAD
INVENTOR

ATTORNEY

April 16, 1946. W. S. HALSTEAD 2,398,741

SIGNALING SYSTEM

Filed Sept. 16, 1944 6 Sheets-Sheet 4

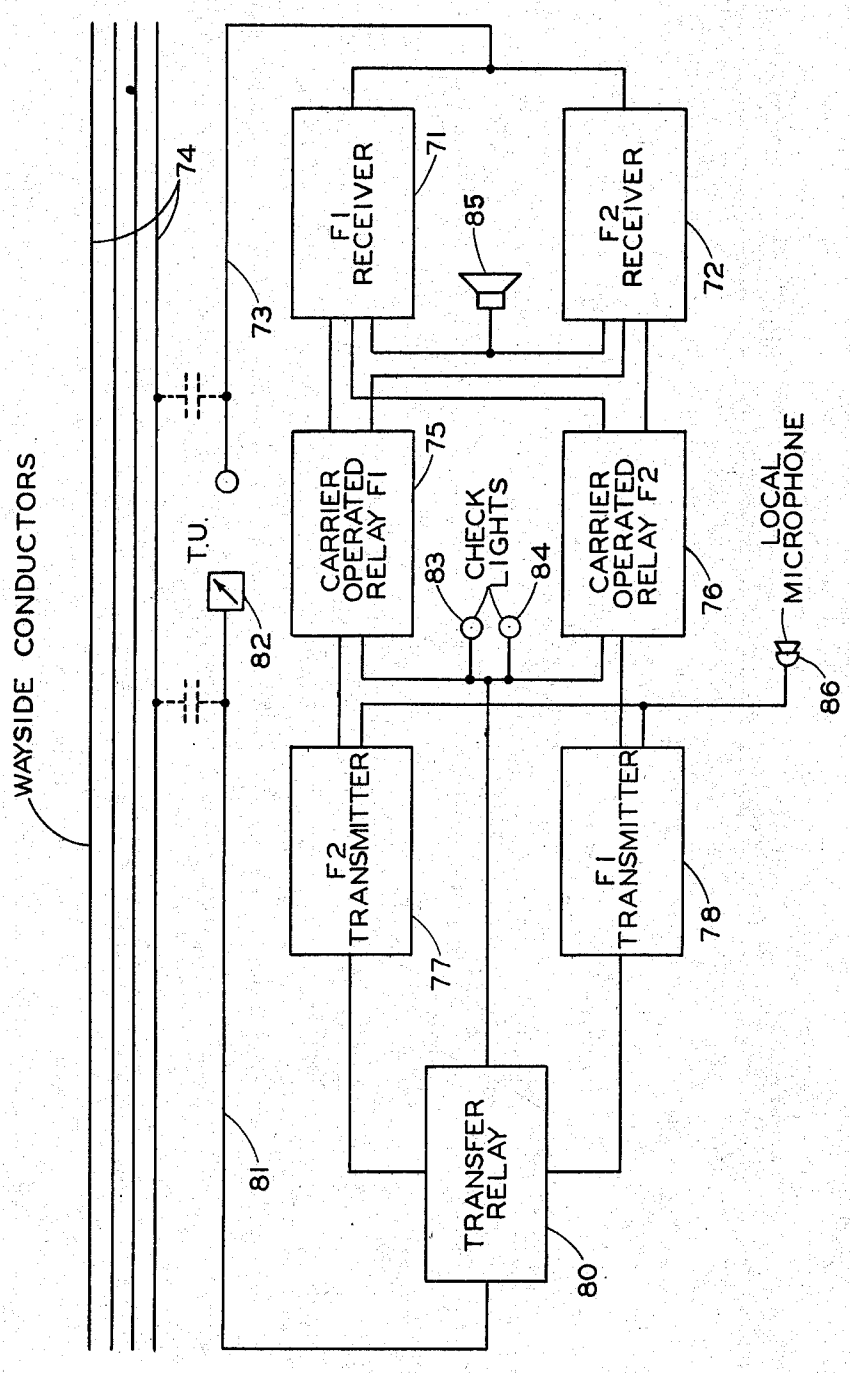


FIG. 4

ZONE REPEATER UNIT

WILLIAM S. HALSTEAD
INVENTOR

ATTORNEY

April 16, 1946. W. S. HALSTEAD 2,398,741

SIGNALING SYSTEM

Filed Sept. 16, 1944 6 Sheets-Sheet 5

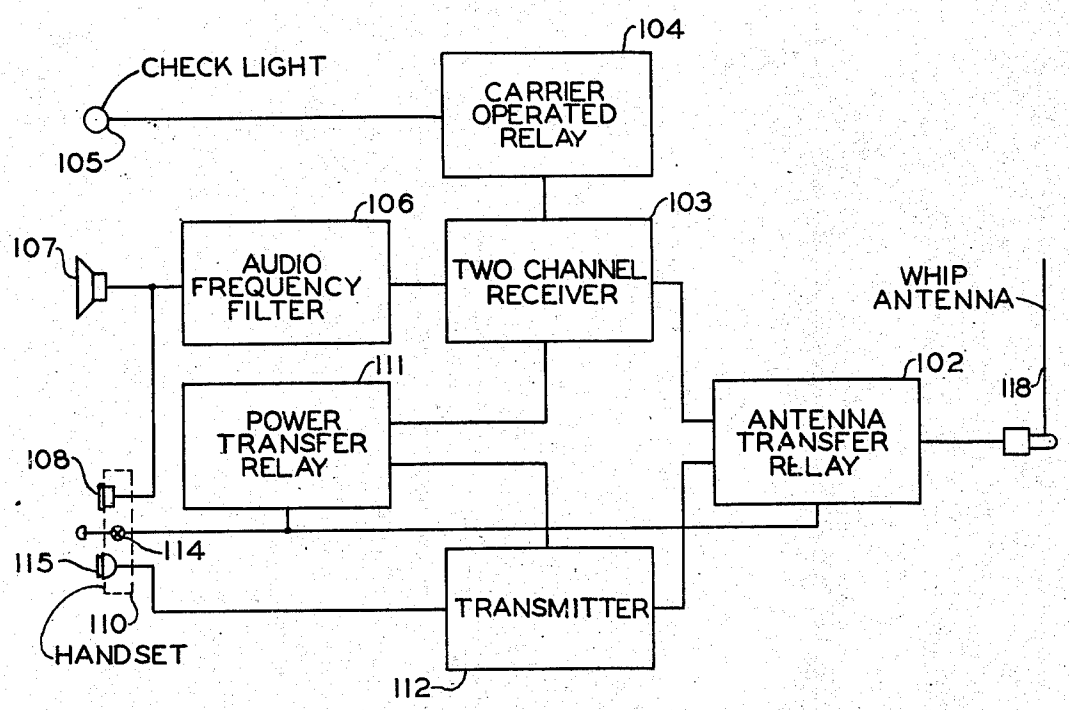
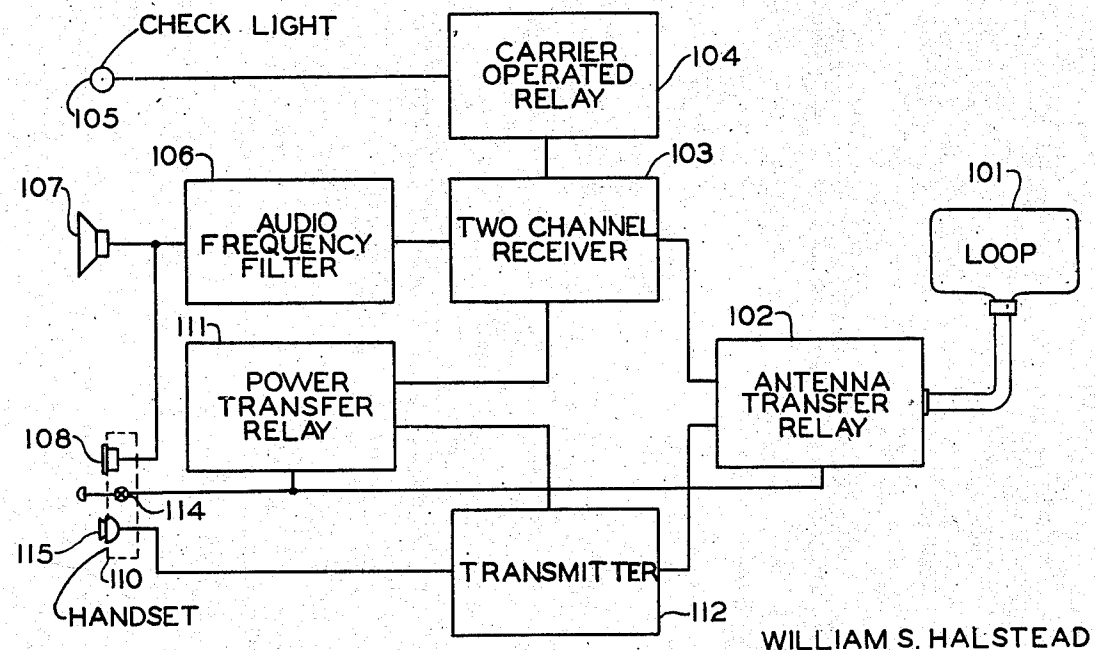


FIG. 6
MOBILE UNIT OPTIONAL



WILLIAM S. HALSTEAD
INVENTOR

FIG. 5
MOBILE UNIT

ATTORNEY

April 16, 1946. W. S. HALSTEAD 2,398,741

SIGNALING SYSTEM

Filed Sept. 16, 1944 6 Sheets-Sheet 6

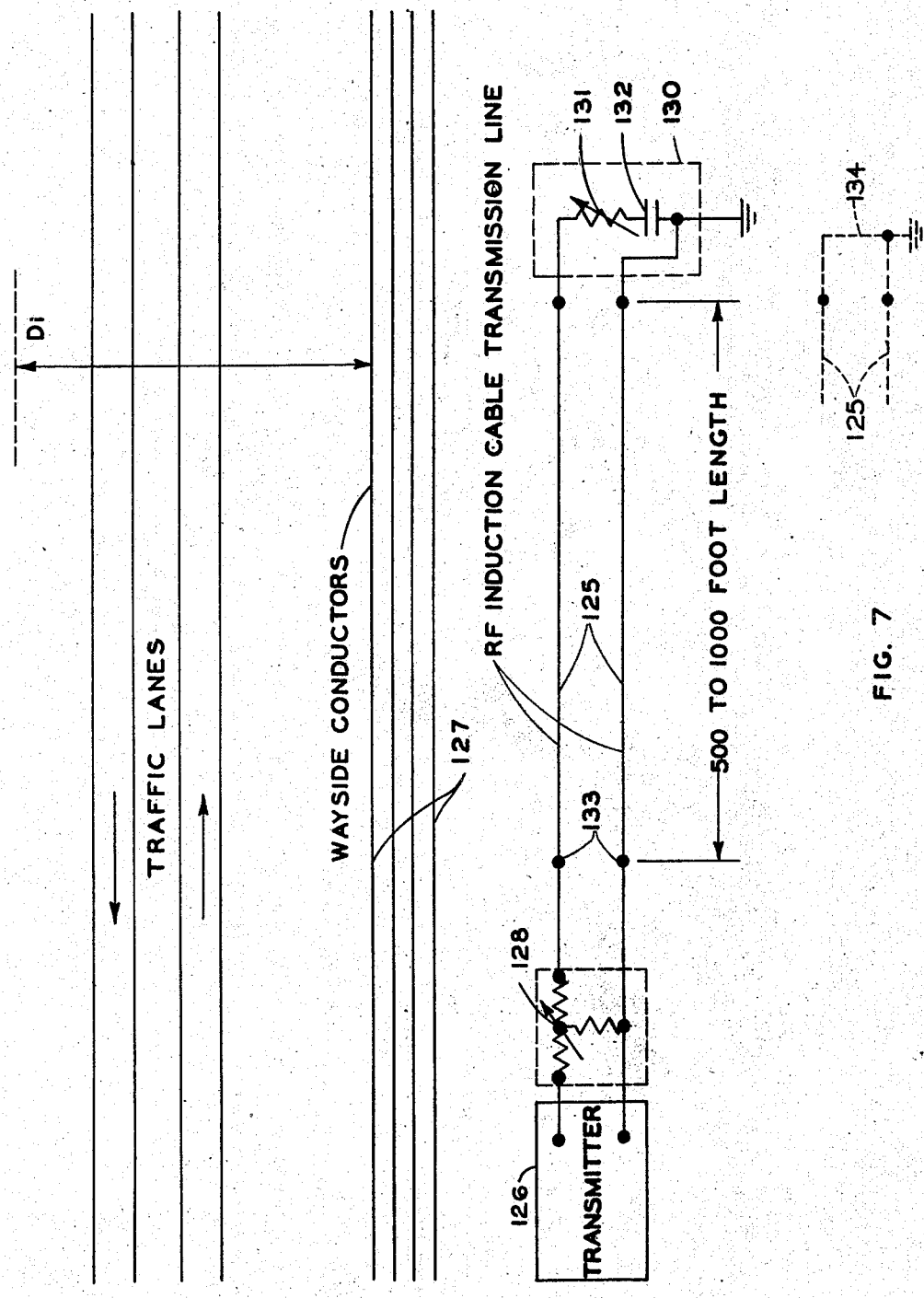


FIG. 7

WILLIAM S. HALSTEAD
INVENTOR

Herbert L. Smith
ATTORNEY

Patented Apr. 16, 1946 2,398,741

UNITED STATES PATENT OFFICE

2,398,741

SIGNALING SYSTEM

William S. Halstead, Purchase, N. Y., assignor, by mesne assignments, to Farnsworth Television & Radio Corporation, Fort Wayne, Ind., a corporation of Delaware

Application September 16, 1944, Serial No. 554,439

11 Claims. (Cl. 179—82)

This invention pertains to an induction radiotelephone system for longitudinally extending traffic lane communications employing wayside wires, adjacent railway trackage or highways, as transmission media for establishing long-distance two-way communications between mobile units, fixed wayside points and mobile units, or between fixed wayside points.

The system of the invention also utilizes a single automatic repeater or an automatic relay group extending in a longitudinal direction along a traffic lane comprising a plurality of zone transmitters and receivers disposed at strategic zone control points along the traffic lane, with means for utilizing the zone transmitters and receivers as automatic repeaters under carrier control from a central point, or operable under localized zone control. In this manner, the longitudinal radiotelephone network is divided into an additional zone or a series of zones, each under local control and/or centralized control. The repeaters are instrumental in extending the effective induction field surrounding the wayside wires over required longitudinal distances with respect to the traffic lanes, while the amount of carrier signal energy impressed on wayside wires in each zone may be limited to effect the necessary restriction in the lateral extension of the field. The system differs from conventional carrier-current systems or ordinary induction telephone systems in that no physical connections need be made to wayside wire circuits, mobile units may establish communications over long distances via induction radio signals impressed on wayside wires and an associated repeater or repeaters, no matching networks are utilized, signals are impressed in phase on all wayside circuits, such as telephone, telegraph and electric power lines, and the combined induction and radiation fields surrounding wayside conductors or loop inductors are employed for two-way signaling purposes.

In general, the system employs a central station transmitter wherein carrier signals are generated, thence modulated and applied to the distributing media so that it may be received, and repeated if desired by a single repeater or a plurality of zone repeater stations, each of which transmits the signal on a frequency different from that used by the preceding transmitter. The zone station may also be used as a local control station, with local or remote microphone and loudspeaker, without acting as a repeater.

By utilizing such retransmission of signals on different frequencies in alternate signaling areas or zones, and by the use of frequency modulation transmitters and receivers, the system is capable of propagating the original signal through a substantially indefinite distance wherever a suitable metallic-path transmission medium or distributing network is available regardless of whether the signal originates at the central station, from one of the zone transmitters, or from a mobile unit. The repeater transmitters may also be used for zone communications. By using the repeater stations as set forth herein, any mobile unit, such as a train, truck, bus, or other vehicle can be in constant communication with a central station, a local zone control station, or with other vehicles.

An important distinction between a conventional space radio system and the induction radio system of this invention resides in the fact that where wayside wires are present radio-frequency signal energy is required to travel through ether, as a transmission medium, only for the relatively short distance between the mobile unit and the wayside wires, which then serve as a transmission medium along the traffic lane.

For vehicle to vehicle communication, for example, induction radio signals do not have to directly bridge the airline distance between the two units, which may be many miles, but travel from one mobile unit to adjacent wayside wires, then along the wires, and thence to the second mobile unit. By means of a repeater associated with these wires the signals from the mobile units may be retransmitted at much higher level, thereby over-riding noise levels. In this process, which may be provided by the system of the invention, signals from a low-power transmitter on a mobile unit are transmitted for a distance of a few feet to wayside wires and the signals as impressed on the wayside wires travel along them to the nearest automatic repeater, at which point the signals are re-transmitted at high level along the same line, utilizing a second frequency for this purpose. The intense induction radio field surrounding the wayside wires is then used by a second mobile unit adjacent the wires in reception of the signals. In this manner, and by a reversal of process so that signals from the second unit are transmitted back through the repeater circuits, effective two-way communication may be established, even though extremely low-power transmitters and relatively insensitive receivers are used on the mobile units. It is pointed out that the repeater station used in the process may be a telephone substation or exchange where interconnections with telephone lines or space radio circuits may be made.

Mobile units may employ receivers capable of receiving on at least two different frequencies and may transmit on one frequency so that regardless of the geographical location of the mobile unit in relation to the distributing media, the mobile unit can always be reached and can communicate with the central station or zone control points. In normal operation the central station and mobile unit may have dual or single channel receivers capable of receiving the central station and moblie unit frequencies as well as the automatic repeater frequencies. The zone receiver used in the automatic repeater equipment may be either of the dual or single channel type depending upon whether the system requires only a single automatic repeater equipment or a multiple of zone repeaters which may be arranged in cascade or tributary connection with respect to a longitudinally-extending wire network, in order to cover a desired length of railway or highway system. To enable the fixed-station network and all cooperating mobile units to operate on the "safe-fail" principle, which is substantially equivalent to the closed-circuit type of supervision on conventional signaling systems employing metallic connections, a checking or test pulse system is employed whereby the central station periodically sends out a master checking pulse over the distributing network, which pulse is received at the repeater stations as well as in the mobile unit or units. In this manner the repeaters retransmit the test pulse along the relay network. A pulse-actuated check light is provided at each of the repeater stations so that the proper operation of the system may constantly be made known to the operators at all fixed stations as well as mobile units.

At the central station there is also a transmitter check light which is connected with a monitor receiver so that there may be a check on the operation of the transmitter at the central station to indicate that the signal is being impressed upon the distributing media.

One object of the present invention is the provision of a traffic control system in which the initial signal is repeated non-interferingly by an automatic repeater or by a multiple of automatic repeaters distributed throughout the system.

Another object of the present invention is the utilization of the wayside conductors inductively to permit one or more successive "repeat" signals to be projected from an initiating point along the system with no interference between signals from adjacent repeater stations.

Still another object of the present invention is the utilization of a right-of-way to be divided into one or more zones and the wayside conductors paralleling such right-of-way, so that a signal initiated in one zone is successively received and repeated along the system to provide a non-interference signal system along the right-of-way.

Another object of the present invention is the utilization of one or more automatic repeaters to pick up and relay signals from one or more mobile units to the central control point or to provide communication between two or more mobile units by means of one or more automatic repeater units along the right-of-way.

A further object of the invention is to provide an R. F. induction cable transmission line disposed substantially parallel with and adjacent the wayside wires or other conductors of the transmission media, so that the signal induced in the transmission media from the R. F. induction cable will be in phase and of substantially equal intensity in the various wires of the transmission media, thus increasing the efficiency of the system in some instances by having the signal which is transmitted through the transmission media in phase in all of the conductors of the transmission media, and thereby reducing the attenuation in the transmission line which in turn permits a reduction in signal intensity at the transmitter. However, this might not be the case in the event the signal impressed upon the transmission media was not in phase in the various conductors thereof.

A further object of the invention is to provide a communications system employing wayside conductors or the like as a transmission media in conjunction with a plurality of relay stations, each consisting of at least one transmitter and one receiver for communications between relay stations disposed adjacent the transmission media along a traffic lane and mobile units on the traffic lane, each of said relay repeater stations, mobile units, and a central control station having aural transducers and/or visual indicators for receiving test pulses transmitted from a central control station to provide an audio-visual supervisory means for the "safe-fail" type to test the integrity of the system at all times.

A further object of the invention is to provide a communications system of the class described employing a metallic transmission media disposed along a traffic lane with a central station employing at least one transmitter and one receiver, and at least one repeater relay station employing at least one transmitter and one receiver, in conjunction with equipment on a mobile unit which utilizes at least one transmitter and one receiver so that at all times communication is possible between the central station and the repeater stations and mobile units, or between any combination of mobile units, relay repeater stations, and the central station.

A further object of the invention is to provide a communications system of the class described wherein a signal is impressed from a transmitter on to a metallic transmission media extending along a lane of traffic in such manner that the combined induction and radiation fields surrounding the transmission media will have sufficient signal intensity to provide an adequate signal for reception by mobile units substantially within a lateral distance in feet equivalent to $157{,}000/f$ (kc.), where f is the frequency in kilocycles, to the end that the signaling fields surrounding the transmission media are substantially ineffectual in producing a useful or interfering signal at distances in feet greater than $157{,}000/f$ (kc.), from the transmission media.

An additional object is the provision of an induction radio-telephone signaling system for use substantially in a longitudinal direction along extended traffic lanes over long distances wherein a strong signal may be provided in all mobile units on or adjacent said lanes at all points regardless of existence of localized areas in which underground conduit, underwater cables, tunnels, or bridges may render ordinary non-repeater types of induction radio systems ineffective.

In the drawings:

Fig. 1 is a block diagram showing a traffic lane communications system with a central stations unit and an automatic repeater station unit.

Fig. 2 is a block diagram showing a traffic lane

communications system with a central station unit and a series of automatic repeater stations.

Fig. 3 is a block diagram showing one form of a central station unit.

Fig. 4 is a block diagram showing a typical zone repeater unit.

Fig. 5 shows a block diagram of a mobile unit employing a loop for pickup from the wayside wires, and transmission thereto.

Fig. 6 shows a block diagram of a mobile unit with a whip antenna as an optional method of pickup, or transmission.

Fig. 7 is a schematic diagram of a radio frequency induction cable transmission line as used by a central station or repeater transmitter unit.

With reference to the drawings and particularly block diagram Fig. 1 thereof, numeral 151 designates the existing wayside conductors running parallel to the traffic lanes 152. The illustrative central station equipment may consist of a receiver or receivers 153, such as is shown in my copending application Serial No. 548,962, receptive to frequencies F1 and F2, a loudspeaker 154, a pulse lock-out relay 156, a received carrier pilot 159, a single channel transmitter 157, such as is shown in my copending application Serial No. 548,962, operating on frequency F1 having coupled to it a microphone 158, an automatic pulsing unit 160, and a tone generator 161. The radio frequency output from the transmitter 157 may be coupled through an R. F. attenuator 163 to the transfer relay 164. The R. F. input to the receiver 153 may also be coupled to the transfer relay 164 so that when the above-mentioned relay is in "receive" position, an R. F. induction cable 165 is connected to said receiver. The R. F. induction cable 165 usually extends for a distance of from 500 to 1000 feet parallel and in close proximity to the wayside conductors 151 and in some instances terminates in terminating unit 166. In lieu of the induction cable coupling means, a line coupling condenser 165A may be used between the transfer relay 164 and wire circuits 151.

The automatic repeater unit consists of a receiving antenna 171, running parallel to the wayside conductors 151 and connecting to a zone receiver 170, said receiver being responsive, for example, to frequency F1. In lieu of the receiving antenna, a line coupling condenser 171A may be used between the input of zone receiver 170 and wayside wires 151. The zone receiver 170 has an audio output connecting to the loudspeaker 175 and to the zone transmitter 176. An additional output from the zone receiver connects to the carrier operated relay 174 which in turn automatically controls the operation of the zone transmitter 176 whenever a signal is received on the receiver 170. The R. F. output circuit of the zone transmitter 176, which may be tuned to a frequency F2, is coupled through the R. F. attenuator unit 177 to the radio frequency induction cable 180 which in turn runs parallel to the wayside conductors 151 and terminates, in this illustrative application, in terminating unit 181. The output circuit of the zone transmitter 176 may also be connected through a line coupling condenser 180A, to wayside wires 151 in instances where the induction cable is not used. The microphone 182, which of course may be any distance away, is provided for the local operation of the repeater equipment and the check light 184 is provided to indicate that the receiver and carrier operated relay are functioning properly.

The mobile unit 185 coupled to the loop 186, in this illustrative example, is equipped with a two-channel receiver tuned to frequencies F1 and F2, and a transmitter tuned to frequency F1.

In the operation of the above described units, the use of the single repeater allows the system to have an extended range of twice that of the central station equipment without a repeater. When the mobile unit is in the central station zone, signals can be transmitted between the mobile unit and the central station on frequency F1. When the mobile unit is in the automatic repeater zone, the F1 signals from the central station or the mobile unit, as the case may be, are automatically received by the zone receiver on F1 and automatically repeated on frequency F2, by the zone transmitter.

Where wayside wires 151 may leave overhead poles and go underground in conduit, or enter lead sheathing, or where wayside wires leave traffic lanes and run over a hill while the traffic lane goes through a tunnel, supplementary wires, such as 140, Fig. 2, may be inductively or capacitively coupled to wayside wires where they approach the points where the wires leave the vicinity of the travel lane for a short distance go into sheathing, or enter underground or underwater cables. At these points, the supplementary wire may be coupled to one or more existing wayside wires, by capacitors 141 and 142, or by induction coupling in which the supplementary wire is simply disposed in the vicinity of the existing wayside conductors. The supplementary wire then bridges the gap in which the existing wayside wires are ineffective for induction radio purposes.

As both the central station and the automatic repeater units of the illustrative application of the system are equipped with dual-channel receivers capable of selectively receiving F1 and F2 frequencies they can readily pick up the signals from the automatic repeating zone transmitter operating on frequency F2.

Fig. 2 represents a more elaborate system which consists of a central station equipment and one or more automatic repeater units to cover an extended longitudinal distance. In this figure, block 11 represents a typical central station unit which includes a transmitter operating on a frequency specified as F1, a dual or two-channel receiver responding to frequencies F1 and F2, with a microphone 12, a loudspeaker 13 and three check lights 14, said central station unit operating in an area specified as zone 1. A radio frequency induction cable transmission line 15 connects to the RF output terminals of the said central station unit and extends for a distance of from 500 feet to 1,000 feet parallel to and in close proximity to the wayside conductors 16, and terminates in the terminating unit 17, said RF induction cable transmission line being used for reception as well as transmission of signals at the central station.

A mobile transmitting and receiving unit 18 employing a loop 20 for both reception and transmission may be installed on a train, automobile or other moving vehicle 19, operating on a traffic lane. This is more clearly illustrated in the external view as a mobile transmitter and receiver 18', the transmitter operating on frequency F2 and the dual channel receiver operating on frequencies F1 and F2. The mobile unit employs a loop 20', said loop usually being mounted in a vertical plane parallel to the wayside conductors 16 along the traffic lane so that a maximum

transfer of energy takes place between the loop 20 and the wayside conductors 16, or vice versa.

Zone repeater units are located at zone control points along the traffic lane as illustrated by zone 2 repeater 22, consisting of a combined two-channel receiver and a two-channel transmitter with associated controls, operating on frequencies F1 and F2. Coupled to said zone repeater for local control is a microphone 23, a loudspeaker 24, and a check light 25. Means for coupling the repeater 22 to the wayside conductors 16 are provided by the receiving antenna 26 and the RF induction cable transmission line 27 ending in the terminating unit 28, said receiving antenna and transmission line extending parallel to and in close proximity to the wayside conductors 16. Other similar zone repeaters are installed at various points along the traffic lane as required, the determining factor for spacing between installations normally being governed by the amount of signal attenuation along the railroad right of way or traffic lane, as the case may be, the desirability of the installation of a zone repeater at certain strategic control points, or the necessity for signal reinforcement at points where wayside wires go underground, enter conduit, cross hills (while trackage goes through tunnels), enter submarine cables to cross rivers, or where local noise levels are excessive and signal energy must be increased.

The operation of the system is such that when the central station 11 transmits on frequency F1 the receiver of the zone 2 repeater 22 receives the signal on frequency F1. This serves to automatically turn on the associated repeater transmitter as described hereafter, the original then being retransmitted on frequency F2. The receiver of zone 3 repeater 29 receives the signal on frequency F2 and automatically retransmits the signal by means of its associated repeater, operating on frequency F1 or other suitable frequency. Thus it is seen that alternate stations operate on alternate or differing frequencies automatically retransmitting the originating signal along the entire circuit.

Due to the fact that frequency modulation is employed, as described hereafter, and that the stronger or initiating signal assumes control with no audible heterodyne effects between signals from alternate zones, the signal from zone 3 repeater 29 on frequency F1 do not interfere with the initial signal from the originating station, even though the same frequency is employed. This condition is a characteristic of frequency modulation, which to a considerable extent makes the system of the invention practicable as the original controlling signal will maintain control of the zone receiver next in line but not in the reverse direction.

A block diagram of the central station unit is more clearly shown in Fig. 3. The transmitter 40, operating on F1 frequency has associated with it a tone generator 41, connected to an automatic pulsing unit 42 said pulsing unit sending out a tone pulse approximately every five seconds. This pulse provides a definite check along the entire system indicating that all zone and mobile units are functioning satisfactorily. The two channel receiver 44 connects to the loud speaker 45, the handset 52 and the carrier-operated relay 46, contacts of the said carrier-operated relay connecting to the received carrier pilot light 47 which indicates visually the presence of an incoming signal. The carrier-operated relay 46 also controls the automatic pulsing unit 42 by locking it out of the circuit, that is, suspending operation of the pulsing unit, when an incoming signal is received.

Associated with the central station unit is a power transfer relay 48 which controls the operation of the transmitter 40 and the receiver 44, also controlling the antenna transfer relay 49, the automatic pulsing unit 42 and the transmitter pilot light 50.

The handset 52 consists of a microphone 53, a push-to-talk switch 54 and an ear phone 55. When not in use the handset 52 is placed on a hook or a hang-up box 56 in which position the switch 57 connects the loudspeaker 45 to the two-channel receiver 44. When the handset 52 is removed from the hook or the hang-up box 56, the switch 57 opens, thereby disconnecting the loudspeaker 45 from the receiver 44. The dispatcher or operator is then in control of the central station unit with the earphone 55 connected to the receiver 44. When the push-to-talk switch 54 is pressed, the power transfer relay 48 and the antenna transfer relay 49 are closed, thereby transferring the RF induction cable 60 from the receiver 44 to the transmitter 40. At the same time the automatic pulsing unit 42 is made inoperative, the transmitter pilot light 50 is turned on and the two-channel receiver 44 is made inoperative. Upon completing the message the push-to-talk switch 54 is released by the operator causing the power transfer relay 48 and the antenna transfer relay 49 to open, resulting in connecting the RF induction cable 60 back to the two-channel receiver 44, placing the said receiver in operation, turning off the transmitter pilot light 50 and again starting the operation of the automatic pulsing unit 42.

The automatic pulsing unit 42 controls the power transfer relay 45 in the same manner as when the push-to-talk switch 54 is closed except that the tone generator pulse is transmitted over the circuit instead of the voice.

A monitor rectifier 62 coupled to a relay 63, said relay operating the transmitter check light 64 is coupled to the RF output of the transmitter 40 by pick-up lead 65 to indicate that the transmitter is functioning properly.

In Fig. 4 a dual channel zone repeater station is indicated in a block diagram form. A two-channel receiver which for clarity is shown as two receivers 71 and 72 adjusted to frequencies F1 and F2 respectively, is coupled to the receiving antenna 73, said receiving antenna running parallel and in close proximity to the wayside conductors 74. The dual channel receiver outputs connect to their respective associated carrier operated relays 75 and 76, which in turn control the operation of the transmitters 77 and 78, the transfer relay 80 and the check lights 83 and 84. The transfer relay 80 connects to the RF induction cable 81, said cable running parallel and in close proximity to the wayside conductors for a distance of from 500 to 1000 feet and terminating in the terminating unit 82.

Associated with the zone repeater is a loudspeaker 85 and a local microphone 86 to be used when local control of the zone repeater is desired. The microphone 86 controls the transmitter of the frequency desired.

In the operation of the zone repeater, an incoming signal on F1 receiver 71 controls its associated carrier operated relay 75 so that it operates both the transfer relay 80 and the transmitter 77 resulting in automatically repeating the signal on frequency F2 back through the RF induction

cable 81 and thence into the wayside conductors 74. At the same time it controls the operation of the check light 83 indicating that the repeater is in operation and blocks the receiver 72 which is adjusted to frequency F2 so that it will not function.

Should an incoming carrier on frequency F2 be picked up by the receiver 72, the carrier operated relay 76 controls the transmitter 78 and connects the said transmitter 78 through the transfer relay 80 to the RF induction cable 81, resulting in automatically repeating the incoming F2 signal on frequency F1. At the same time other functions including the operation of the check light 84 are carried out in the manner outlined in the operation of the repeater with an incoming signal on F1.

Fig. 5 shows a block diagram of one form of the mobile unit equipment employing a loop for induction pickup from the wayside conductors and consists of a loop 101 coupled through an antenna transfer relay 102 to a two channel receiver 103. A carrier operated relay 104 also connects the receiver 103, contacts of said carrier operated relay 104 operating a check light 105. The check light 105 operates when short pulses are transmitted from the central station and is used as a constant check on the operation of the circuit. The audio output from the dual receiver 103 passes through the audio frequency filter 106 which filters out most of the pulse frequency so that it will not be objectionable to the operator but passes the voice frequencies to the loudspeaker 107 and the earphone 108. The antenna transfer relay 102 is normally in the receiving position.

When the operator desires to transmit a message or reply to a message originating at the central station or zone repeater, the press-to-talk switch 114 on the handset 110 is closed, resulting in the operation of the power transfer relay 111 and the antenna transfer relay 102. The power transfer relay 111 then shifts the receiver 103 to an inoperative position and at the same time places the transmitter 112 in operation on frequency F2. In the transmitting position, the antenna transfer relay 102 connects the transmitter 112 to the loop 101 and the operator can then transmit his message through the microphone 115. By releasing the button on the press-to-talk switch 114 the mobile unit is again placed in the receiving position so that frequencies F1 and F2 may be received.

Fig. 6 shows a block diagram of an identical mobile unit equipment except that a whip antenna 118 is employed in place of a loop as an optional method for pickup from the wayside conductors.

Fig. 7 shows an RF induction line transmission conductor or cable 125 as an efficient means of coupling a transmitter 126 to the wayside conductors 127, said RF induction cable transmission line 125 running for a distance of from 500 to 1000 feet parallel and in close proximity to the wayside conductors 127 and terminating in a termination unit 130. The transmission cable 125 may consist of any standard impedance cable of from 72 ohms to 600 ohms impedance. The termination unit 130 (which may be considered as typical of such units previously mentioned) consists of a non-inductive variable resistor 131 in conjunction with a capacitor 132. By adjusting the resistor 131 to the correct value it is possible to eliminate standing waves in the RF induction cable transmission line by matching the characteristic impedance of the line used, resulting in confining the signals substantially to the wayside conductors 127 and their immediate fields.

An alternative and equally efficient method of coupling is to employ a transmission line 125 as a loop of extremely long top and bottom sections with wide spacing between ground return and the high side of the loop, the far end of which may be grounded as shown at 134. This loop is in a vertical plane, parallel to the traffic lane. The lower side of the loop can be a wire, a steel rail, a pipe, or equivalent conductor running parallel to the wayside conductors and grounded at the far end, as indicated.

In either system of coupling the transmitter to the wayside conductors, the radio frequency attenuator 128 allows the output of the transmitter 126 to be adjusted to such a value that the lateral extension of the induction field Di can be maintained within desired limits.

From the foregoing description taken in conjunction with the drawings, it is evident that there is provided a traffic lane communicating system that ensures against interference and tends to assure desired signaling from one zone to the other successively and successfully.

It will be appreciated from the arrangement of the zone receiver-repeater apparatus as set forth, in which repeater units are used at such points as may be required at signal attenuated within a predetermined range, that each zone will receive selected signals without interference by or with the signals of the initial apparatus or adjacent zones.

What is claimed is:

1. In a traffic communications system having a primary signaling zone extending along a right of way divided into two secondary signaling zones, wayside conductors along the right of way, a central station including at least a transmitter and receiver inductively associated with said wayside conductors and operative with modulated carrier frequencies, and a zone transmitting and receiving relay unit inductively associated with said wayside conductors, said relay unit including means whereby a received signal having one carrier frequency characteristic is retransmitted at a different carrier frequency characteristic than the received signal, said retransmitted signal being inductively imposed back onto the wayside conductors, with the same modulation characteristics as originally impressed upon the signal at said central station.

2. In a traffic communications system having a primary signaling zone extending along a right of way divided into secondary signaling zones, wayside conductors along the right of way, a central station including at least a transmitter and receiver of modulated carrier frequencies inductively associated with said wayside conductors, and a plurality of zone transmitting and receiving relay units inductively associated with said wayside conductors, each of said relay units including means whereby a received signal having one carrier frequency characteristic is transmitted at a different carrier frequency characteristic than the received signal and inductively imposed back onto the wayside conductors, both said received and said re-transmitted carrier signals having substantially the same modulation characteristics.

3. In a traffic communications system having a primary signaling zone extending along a right of way which is divided into secondary signaling

zones, wayside conductors extending along the right of way of sufficient distance to embrace the primary signaling zone, a central station including at least a transmitter and receiver of modulated carrier frequencies inductively associated with said wayside conductors, and a plurality of relay units having transmitting and receiving means therein inductively associated with said wayside conductors, each of said relay units including apparatus for receiving a signal on one carrier frequency and retransmitting said received signal on a different carrier frequency, said relay units disposed along said right-of-way each transmitting its received signal on a carrier frequency different than the transmitter in its adjacent zone on either side thereof, said respective carriers all bearing substantially identical modulation characteristics, whereby intelligence is propagated from zone to zone with substantially no loss of distinguishing modulation characteristics.

4. In a traffic communications system having a primary signaling zone extending along a right-of-way divided into secondary signaling zones, wayside conductors along said right-of-way, an initiating carrier signal means capable of initiating induction radio signals at one carrier frequency, the said carrier signal means being inductively coupled with said wayside conductors, and a plurality of signal receiving and a transmitting means disposed at secondary signaling zones along said right-of-way, said receiving and transmitting means being employed in each secondary zone for receiving and successively repeating the initiated signals along said right-of-way, each signal receiving and repeating means being inductively associated with the wayside conductors, the repeating means also being capable of originating carrier signals, the signal thus initiated being alternately repeated in successive zones along said right-of-way at different carrier frequencies to ensure a non-interfering signal throughout the system.

5. In a traffic communications system having a primary right-of-way signaling zone divided into secondary zones, wayside conductors extending throughout said right-of-way, a primary initiating signal means capable of initiating signals at one carrier frequency, said signal initiating means being inductively coupled with said wayside conductors, a plurality of signal repeating means disposed in each of said secondary zones along said right-of-way, for receiving and successively repeating the signal initiated at the primary signal initiating means along said right-of-way, each signal repeating means being inductively associated with the wayside conductors, the repeating means also being capable of originating carrier signals, the signal thus initiated by the repeater means being alternately repeated in successive zones at different carrier frequencies to ensure a non-interfering signal throughout the system, and a mobile unit movable along the right-of-way having a two-way radio apparatus carried thereby and being inductively coupled with the wayside conductors to permit two-way radio communication with the initiating signal means and the repeating means of the zone apparatus.

6. In a traffic communications system having a primary right-of-way signaling zone divided into secondary zones, wayside conductors along the right-of-way, a central transmitter station inductively coupled with said wayside conductors, a zone repeater for each of said secondary zones, each repeater including a receiver and a transmitter inductively coupled with the wayside conductors, the signals received on one frequency being re-transmitted by the zone transmitter on a different frequency, and a mobile unit movable along the right-of-way having a two-way radio apparatus carried thereby and being inductively coupled with the wayside conductors to permit two-way radio communication with the central transmitter station and any of said zone repeaters.

7. In a traffic communications system having a primary right-of-way signaling zone divided into secondary zones, wayside conductors along the right-of-way, a central transmitter station inductively coupled with said wayside conductors, a zone repeater for each of said secondary zones, each repeater including a receiver and a transmitter inductively coupled with the wayside conductors, the signals received on one frequency being re-transmitted by the zone transmitter on a different frequency, and at least two mobile units movable along the right-of-way, each of said mobile units having a two-way radio apparatus carried thereby and being inductively coupled with the wayside conductors to permit two-way radio communication between said mobile units through one or more zone repeaters.

8. In a radio signaling system effective in two-way communications with vehicles throughout the length of a longitudinally-extending traffic lane and within a limited lateral distance from wayside conductors normally extending parallel to the traffic lane wayside conductors, a radio relay group for progressive signaling over said wayside conductors along a traffic lane and disposed in proximity thereto, said relay group consisting of a plurality of carrier wave repeater stations disposed at spaced intervals along said traffic lane, each of said repeater stations having a normally-on receiver complemental to a normally-off transmitter, means for automatically placing each of said transmitters in operation when a carrier signal is received by the transmitters complemental receiver whereby a signal is relayed automatically along said traffic lane, signal transfer means associated with each of said transmitters and receivers for utilizing said wayside conductors as a transmission medium along said traffic lane, whereby the combined induction and radiation fields surrounding said wayside conductors are employed in establishing communications with vehicles proceeding along said traffic lane substantially within a lateral distance in feet of 157,000/f (kc) from said wayside conductors, said fields being ineffective in producing an interfering signal at distances in feet greater than 157,000/f (kc) from said wayside conductors.

9. In a traffic communications system having a primary signaling zone extending along a right-of-way divided into secondary signaling zones, signal propagating means associated with said right-of-way for establishing said primary signaling zone, a central station including at least a transmitter and receiver operatively associated with said signal propagating means and operative with modulated carrier frequencies, a normally operating check signal source associated with said central station transmitter for applying check signals on said signal propagating means, said signal propagating means including at least one zone receiving and transmitting relay unit, said relay unit including means whereby said

check signal is received with one carrier frequency characteristic and retransmitted with a different carrier frequency characteristic if said relay unit is operative, and receiving means operatively associated with said signal propagating means and responsive to said retransmitted check signal for establishing the integrity of the traffic communications system.

10. In a traffic communications system, an electrically continuous wayside signal transmission medium, a central station including a transmitter and receiver coupled to said wayside medium and operative with modulated carrier frequencies, a mobile station including a transmitter and receiver coupled to said wayside medium and operative with modulated carrier frequencies, a transmitting and receiving relay unit, means for coupling said relay unit with a conductive portion of said wayside medium, said relay unit including means whereby a received signal from either said central station or said mobile station having one carrier frequency characteristic is retransmitted at a different carrier frequency characteristic than the received signal, said retransmitted signal being impressed back onto the said wayside medium with the same modulation characteristics as originally impressed upon the signal at said central station or said mobile station.

11. In a traffic communications system, an electrically continuous wayside signal transmission medium, a central station including a transmitter and receiver coupled to said wayside medium and operative with modulated carrier frequencies, a transmitting and receiving relay unit, means for coupling said relay unit with a conductive portion of said wayside medium, said relay unit including means whereby a received signal from said central station having one carrier frequency characteristic is retransmitted at a different carrier frequency characteristic than the received signal, said retransmitted signal being impressed back onto the said wayside medium with the same modulation characteristics as originally impressed upon the signal at said central station and a mobile station including a transmitter and a multi-channel receiver coupled to said wayside medium, said multi-channel receiver being responsive to all of the modulated carrier frequencies impressed on said wayside medium.

WILLIAM S. HALSTEAD.