Nov. 7, 1933. C. W. GREEN 1,934,423

SYSTEM FOR COMMUNICATING WITH MOVING VEHICLES

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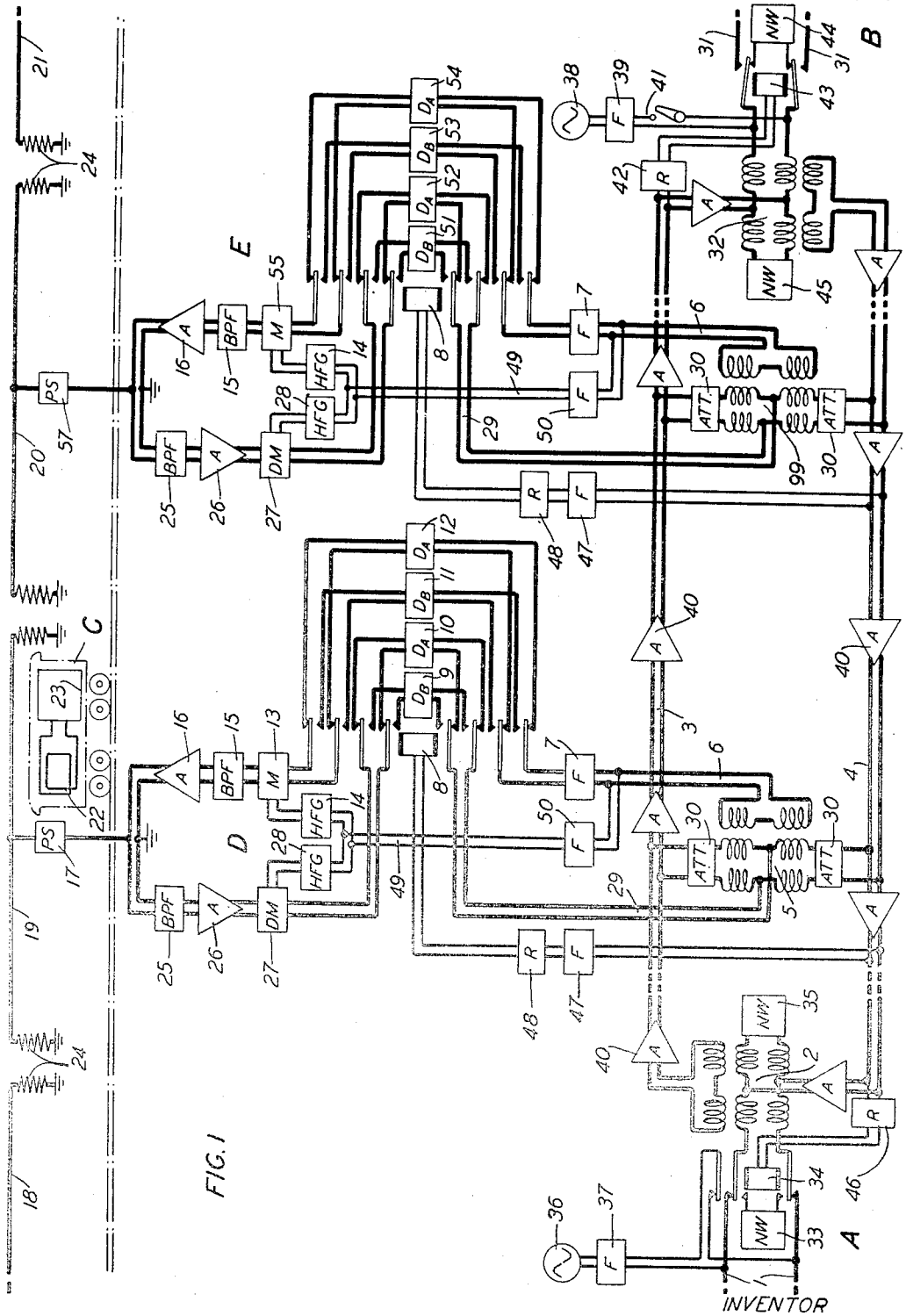

FIG. 1

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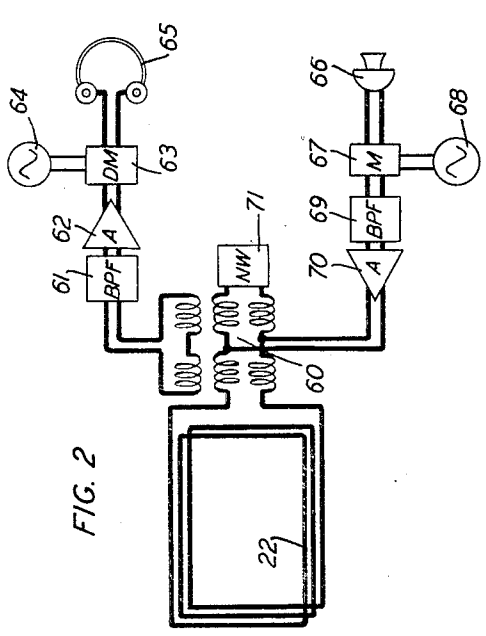

FIG. 2

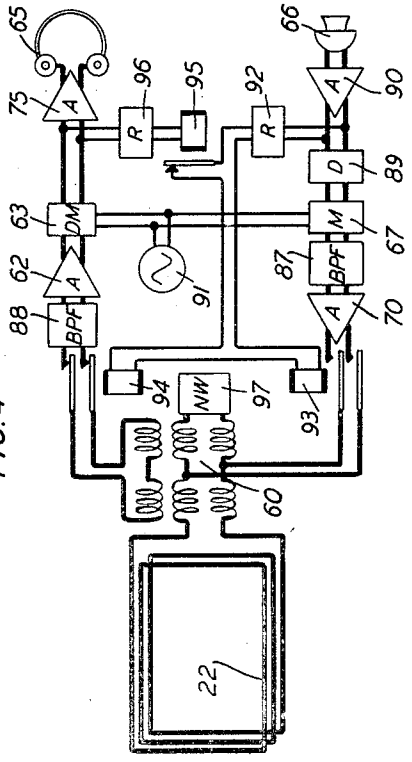

FIG. 4

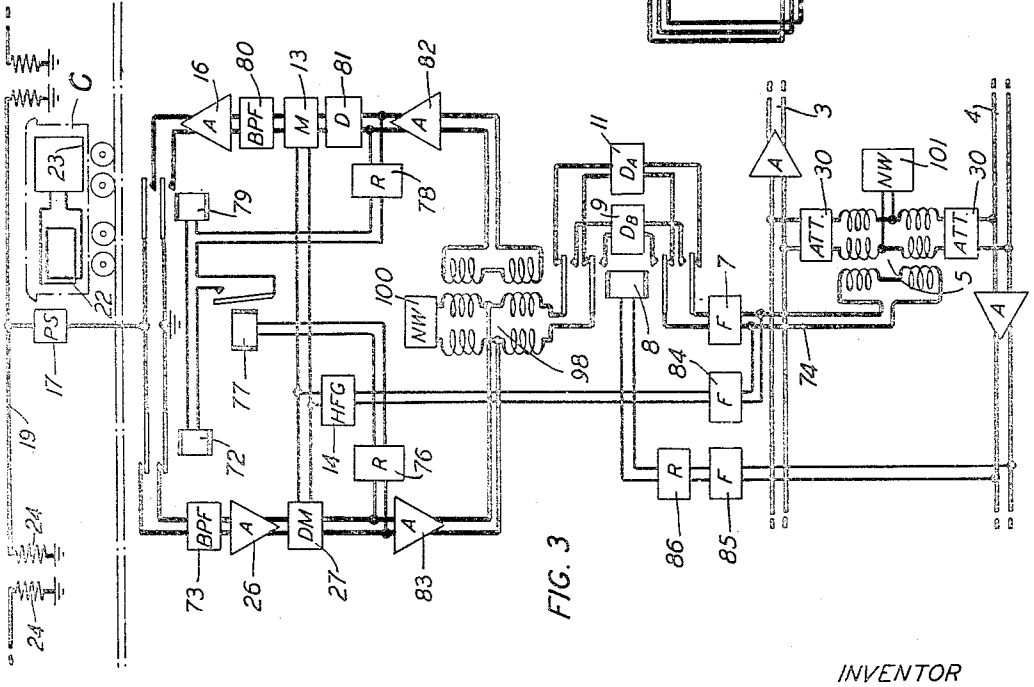

FIG. 3

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SYSTEM FOR COMMUNICATING WITH MOVING VEHICLES

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10 Claims. (Cl. 250—6)

This invention relates to communication systems and more particularly to systems in which communication is to be maintained between a moving vehicle and a fixed station.

It is an object of the invention to improve the transmission between a moving vehicle and stationary signaling apparatus and in particular to reduce fading effects in received signals.

In a system in accordance with the present invention communication is established between a moving vehicle, such as a train, and a fixed station by virtue of the coupling between transmission apparatus on the vehicle and a signaling channel parallel to the path of the vehicle. For efficient transmission it is preferred that a modulated high frequency or carrier wave be used to transmit signals across the gap between the train and the parallel channel. With the same object in view, the parallel channel is divided into a number of separate sections, each section being associated with individual modulating and demodulating apparatus to which the signal is distributed at its original frequency over an auxiliary feeder line and with comparatively little loss. This auxiliary, low frequency channel may be, for example, a cable circuit, an open wire line, or a circuit comprising the sectionalized line itself.

As the train passes from communication with one section to communication with an adjacent section, a fading effect or even a period of non-reception would be observed in the signals received by the train, if it should happen that the two modulated waves transmitted from adjacent ends of the sections were not in the proper phase relation. To obviate this effect means are provided in accordance with the present invention to insure that the phase of a signal wave at the terminal of a section is properly related to that of the wave in the adjacent section. In one specific embodiment, a phase adjusting device is inserted near the feed point of each section to secure the desired result.

Because of the delay occurring in the auxiliary or signal frequency channel, the signal applied to the modulator of one section might differ considerably in phase from that applied to the modulator of an adjacent section if correcting devices were not introduced. The demodulated signals heard on the train when receiving from these adjacent sections simultaneously would consequently be distorted. The same effect would appear also in signals received at the fixed station. Phase delay devices are therefore provided near the junction of the auxiliary line and each section to equalize the time of transmission between the fixed station and each modulator and demodulator.

The nature of the invention will more fully appear in the following detailed description of a specific embodiment of it as used in a train communication system, reference being made to the drawings, in which

Fig. 1 is a schematic diagram of a system embodying the invention in which different frequencies are used for transmission to and from the vehicle;

Fig. 2 shows in detail the transmission equipment on the vehicle in the system of Fig. 1;

Fig. 3 is a schematic drawing of a system in which voice-operated devices are provided for two-way operation; and

Fig. 4 shows in detail the transmission equipment on the vehicle in the system of Fig. 3.

Referring now to Fig. 1 there is shown a system for two-way communication between either of two fixed stations, A and B, and a train C. The main elements of the system may be identified as follows: Parallel to the right-of-way of train C is an elevated line divided into a number of sections, 18, 19, 20 and 21, which are in energy transfer relation with transmission apparatus 23 on board the train. Each section is provided with an individual substation, of which only two, D and E, are illustrated, for demodulating the waves received from the train and for impressing on a carrier wave the voice frequency signals that are to be transmitted to the train. Each substation is associated with the two terminal stations by means of a four-wire voice frequency channel 3, 4, connecting the latter. While only four line sections are shown, it is to be understood that their number may be multiplied as the length of the system, the attenuation of the line and other factors, may require.

With the train opposite section 19 as shown, the path of transmission from station A to train C may be traced as follows: The signals to be transmitted, which may be, for example, telephone signals, arrive over channel 1 from an ordinary telephone exchange and are applied to the two-wire line 3 through the rest contacts of relay 34, which is in its normal condition, and through hybrid coil 2. The latter is balanced by a network 35 and is so connected that lines 3 and 4 are in conjugate relation to each other. At intervals in line 3, which may be an open wire line or other suitable transmission medium, are repeaters or amplifiers 40 of any suitable type. When the signals arrive at substation D, a por-

tion is diverted by hybrid coil 5 to channel 6; the rest continues through line 3 to be distributed to the other substations. The signals in channel 6 pass through filter 7, through the rest contacts of relay 8, which is in its normally released position, through a voice frequency delay network 12, to modulating apparatus 13. Filter 7 prevents a synchronizing wave normally applied to the system from entering the modulator circuit.

The high frequency or carrier wave of frequency f_1 on which the audio frequency signal is impressed is supplied by harmonic frequency generator 14, which may be of the type described in U. S. Patent No. 1,446,752, issued February 27, 1923 to B. W. Kendall. A similar generator is provided at each of the other substations.

The various generators are maintained in synchronism by virtue of their connection to a common base-frequency wave source. During intervals of non-transmission and when station A is in communication with the train, this source is generator 36 located at station A. A similar generator 38 at station B is used only when that station is in communication with the train. The filtered output of generator 36 passes through a rest contact of relay 34, which is normally unoperated, and onto line 1. It is picked up at each substation hybrid coil and transmitted to the respective channels 6. As the frequency selected for this wave is outside the frequency range of signals, a shunting resonant circuit 7 may be used effectively to block it from the modulating apparatus. Filter 50 admits the wave to channel 49 and to the control circuit of the harmonic frequency generator 14. Great latitude is permissible in the selection of the carrier wave frequency; a hundred kilocycles per second was found suitable in one instance.

The modulator equipment 13, to which both carrier wave and telephone signals are supplied, is of the type in which the carrier wave and one sideband are suppressed. This type is well known in the art and is described in detail by E. H. Colpitts and O. B. Blackwell in the Journal of the American Institute of Electrical Engineers, of June, 1921. The output of modulator apparatus 13 is sent through a bandpass filter 15 and amplifier 16 to the elevated line section 19. One terminal of amplifier 16 is grounded, the other is connected, in the embodiment shown, through a phase adjusting device 17 to the midpoint of section 19. The signal traversing line 19 is then transferred by electromagnetic waves to receiving apparatus on the train, which will be described hereinafter. Each half of the several line sections is terminated in its characteristic impedance 24 to prevent reflection phenomena.

Signals transmitted in the opposite direction, i. e., from train C to station A, are impressed by means of the transmission apparatus on the train on a carrier wave of frequency f_2 which differs sufficiently from f_1 to permit separation by band-pass filters of the waves transmitted in the two directions. The high frequency signal is then transmitted across the gap between the train and line 19 and conducted through filter 25 and amplifier 26 to demodulator apparatus 27. Filter 25 is of the band-pass type and highly attenuates all signals outside of the frequency range of the sideband received from the train. Harmonic frequency generator 28, controlled by the same base frequency wave source as generator 14, supplies the demodulator 27, which may be of the type disclosed in the A. I. E. E. publication referred to above, with the carrier wave suppressed in the process of modulation. Its frequency is therefore f_2. The output of demodulator 27, which is a signal of voice frequency, passes through the contacts of relay 8, which as before is in its unoperated condition, traverses delay network 10, and channel 29 to hybrid coil 5, whence it passes over repeatered line 4 to hybrid coil 2 and telephone channel 1 of station A. While sending and receiving channels are in almost conjugate relation, it may be found advantageous to insert the attenuating pads 30 to prevent the establishment of a singing condition in the circuit.

The circuit of Fig. 1 also provides for communication between station B and the train. As noted above, switch 41 at this terminal station is normally open. When station B is to get control of the circuit this switch is closed and the subharmonic or base frequency wave produced by generator 38 energizes line 4. At station A a portion of this wave is diverted, rectified by device 46 and caused to operate relay 34. One contact of this relay opens and thereby removes generator 36 from circuit. Two other contacts closing connect a network 33 across hybrid coil 2, which balances network 35 and prevents reflection phenomena. At the same time telephone line 1 is disconnected. By the removal of generator 36, relay 43 at station B, which is normally energized by rectified current derived therefrom, is released, thereby disconnecting balancing network 44, which corresponds to network 33, and substituting telephone line 31, which may be connected with an ordinary telephone exchange. Upon the energization of line 4 with the base frequency waves, the several substation relays 8 are operated, since the rectifiers 48 with which they are associated are connected to line 4 through filters 47. The latter pass only waves of base frequency. As a result signals passing through the substations either to or from station B are shifted from the delay networks 10, 12, 52, 54 etc. used when station A is transmitting or receiving to a different group of delay networks 9, 11, 51, 53 etc. In other respects the path of signals from line 4 and station B is identical with that of signals from line 3 and station A.

The purpose of the delay networks 9 to 12 and 51 to 54, which may be of the type disclosed in U. S. Patent No. 1,565,302, issued December 15, 1925 to H. D. Arnold, is to correct for distortion that would otherwise occur when the train is near the end of one line section and receiving the signal partly from that section and partly from the adjacent one. When the train, for example, is at the junction of sections 19 and 20 a signal from station A must traverse a longer path to reach the train through substation E and section 20 than to reach it through substation D and section 19. Assuming that the times of transmission through the two substations and elevated line sections are negligible, which is practically the case, the difference in time required is the time it takes for the signal to pass from hybrid coil 5 to hybrid coil 99. As the delay in this circuit may be considerable, especially if an underground cable is used, there may be an appreciable difference in phase of the telephone signals received from the two sections, and distortion will result. The same effect will be observed in signals received from the train. It is to equalize the times of transmission over the two channels just traced, that delay networks 10, 12, 52 and 54 are provided. Similar networks are provided at each of the other substations so that

this equalization may be effected throughout the system.

When communication is to be held between train C and station B a different amount of delay is required at each substation, for in that case it is the signals passing through substations farthest from station B that meet with the greatest delay. Relay 8 is accordingly arranged to switch in the proper alternative delay networks 9, 11, 51 and 53, in the manner described above, whenever station B is to be put in communication with the train.

When the train is at the junction of two sections it receives the modulated high frequency signals from two different sources, viz., the respective modulating circuits of the associated substations. If the waves received on the train from adjacent terminals of these sections are exactly in phase, a maximum level of received signals obtains. If they are out of phase the amplitude of the resultant signal will be less than this maximum, and if in phase opposition the waves will neutralize each other and no signal will be heard. The effect on the signals heard on the train as it passes this junction point will in general be to cause a temporary shift in signal level which may appear to be a fading effect. To prevent this fading effect, means are provided whereby the relative phases of the waves radiated by adjacent sections may be adjusted as described below so that a minimum shift in signal level is observed.

In Fig. 1, each line section is provided with a phase shifting device, 17 in section 19 and 57 in section 20. These phase shifters may be of any suitable type, for example, that described in U. S. Patent No. 1,695,051, issued December 11, 1928 to W. A. Marrison. By means of them the phase of high frequency waves generated by the modulators 13, 55, etc., may be adjusted to suit the particular transmission characteristics of the circuit between the modulators and the terminals of the several line sections 19, 20, etc. The synchronization of the high frequency generators 14 insures that the relative phases of these waves as they are applied to the respective modulators will remain constant. The phase shifters may usually therefore be left fixed once an adjustment has been made. In making this adjustment, phase shifter 17 may be adjusted so that the waves arriving at the left-hand terminal of section 19 are in the desired phase relation with the waves appearing at the right-hand terminal of section 18. The change in signal level may be observed on the train and the proper adjustment thereby determined. With section 19 thus adjusted, the phase shifting device 57 of section 20 is similarly controlled to obtain the desired phase relation at the junction with section 19. The same procedure is followed at each of the other substations. In some cases the desired phase relation may be obtained without the necessity of using a phase shifting device. Thus, when warranted, the length of the various sections may be proportioned or the feed point so determined that the desired phase relation is inherent in the system. It is then necessary only to insure that the oscillators are in synchronism. While the elevated line sections are shown with the substation circuits connected at their midpoints, the present invention is equally applicable to systems in which this is not the case.

Fig. 2 is a schematic diagram of the transmission apparatus aboard train C. Loop 22 represents means for receiving and transmitting the electromagnetic waves that pass between train C and the parallel elevated line. Hybrid coil 60 connects it to conjugately related transmitting and receiving apparatus, the first comprising transmitter 66, oscillator 68, modulator apparatus 67, band-pass filter 69, and an amplifier 70, and the second comprising band-pass filter 61, amplifier 62, oscillator 64, demodulator apparatus 63 and telephone receiver 65. The carrier wave generated by oscillator 68 is of the frequency f_2 which, as stated before, is sufficiently different from f_1 to permit the single sideband produced to be separated readily by means of filters from the sideband received. The modulator apparatus 67 and demodulator 63 may be of the type used at the substations. Oscillator 64 supplies the demodulator with waves of carrier frequency f_1. Band-pass filters 69 and 61 are designed to pass, respectively, only the sideband transmitted and the sideband received.

Fig. 3 shows one substation of a system in which the same carrier wave frequency is used for both directions of transmission. It is similar in many respects, however, to the circuit of Fig. 1. When communication is not in progress the circuit is in condition to transmit signals from the train to terminal station A. The proper condition for transmission in the other direction, i. e., from terminal station A to the train, is established by voice-operated switches. Similarly, to establish communication between station B and the train, the proper connections are made by means of remotely controlled relays.

Tracing the path of a signal from train C induced in line section 19, it is seen to include a phase shifting device 17 as in the system of Fig. 1. Passing then through the contacts of relay 72, which is in its normally unoperated condition, the signals pass through a selective filter 73 adapted to pass only those frequencies represented by the sideband received. They are then passed through amplifier 26 and reduced to their original frequency in demodulator 27. After further amplification they pass through a balanced hybrid coil 98, the rest contacts of relay 8, the delay network 11 which is connected in circuit thereby, band pass filter 7 and channel 74 to hybrid coil 5, and thence to lines 3 and 4. Filter 7 passes waves of signal frequency, but blocks those of base frequency used to synchronize the harmonic frequency generators. The windings of hybrid coil 5 are so connected that a two-way path between channel 74 and the four-wire line 3, 4, is provided.

To the output circuit of the substation demodulator 27 is connected a rectifier 76 which causes relay 77 to be held in its operated position as long as signals are being received from the train. With the contact of this relay thus opened, it is impossible for speech current from a terminal station to operate relay 79 and connect the high level output of modulator 13 to the receiving chanel. When signals are not being transmitted from the train, relay 77 is unoperated and its contact closed, thus permitting a terminal station to get control of the circuit at will.

In the other direction of transmission, that is, from station A to train C, signals from station A enter the substation through channel 74, pass through the contacts of relay 8, delay circuit 11, hybrid coil 98, amplifier 82 and delay device 81 to modulator 13. Harmonic frequency generator 14 supplies both modulator 13 and demodulator 27 with waves of carrier frequency. The single

sideband output of the modulator is filtered in band-pass filter 80, passed through amplifier 16, and the contacts of relay 79 to the phase shifter 17 and the elevated line 19. Relay 79 is operated by speech current through rectifier 78 and the normally closed contact of relay 77. At the same time, relay 72, the windings of which are in series with those of relay 79, is operated to disconnect the demodulator channel. Delay circuit 81, which may be of the type disclosed in U. S. Patent No. 1,565,302, issued December 15, 1925 to H. D. Arnold, is provided so that these several relays will have operated before signal currents reach their contacts. Echoes are suppressed by virtue of a delay in the release of relay 77.

As in the system of Fig. 1, station B gains control of the circuit by closing the switch of its local subharmonic frequency generator. The waves of the latter are selected at the substation from line 4 by filter 85, rectified, and caused to operate relay 8, thereby inserting the proper delay network 9 for communication involving station B.

Fig. 4 shows the train apparatus used in conjunction with the system of Fig. 3. The transmitting channel includes telephone transmitter 66, amplifier 90, delay network 89, which serves the same purpose as network 81 of Fig. 3, and modulator 67. The latter, which is of the same type as that used at the substations, is supplied with carrier waves by oscillator 91. The latter may be of the same type as those represented in Fig. 2. Its frequency is that of the substation high frequency generators 14. When transmitting from the train, the amplified speech current that is rectified and passed through the normally closed contact of relay 95 and the windings of relays 93 and 94, causes the latter two relays to operate, thereby completing the transmitting circuit and disabling the receiving circuit. The output of the modulator, after filtering and amplification, can then be transmitted to the loop 22, through hybrid coil 60. A network 97 is used to balance the loop circuit.

Signals received on the train from the elevated line are transmitted through hybrid coil 60, the normally closed contacts of relay 94, band-pass filter 88 and amplifier 62 to demodulator 63. As the same carrier wave is used for both directions of transmission, the carrier suppressed in the process of modulation may be supplied by oscillator 91.

The detected signals are then amplified and passed to the telephone receivers 65. Rectifier 96 connected to the output of demodulator 63, and relay 95 serve the same purpose as the corresponding elements in the substation, viz., to open the circuit by which the transmitter gets control of transmission and thereby to protect the receiving circuit.

While a specific embodiment of applicant's invention has been described for purposes of explanation, it is apparent that other embodiments and modifications are possible within the scope and spirit of the appended claims.

What is claimed is:

1. In a system for communicating with a moving vehicle, signal receiving apparatus on said vehicle, a transmission line divided into a plurality of conductor sections adjacent to and extending along the path of travel of said vehicle adapted to transmit waves to said receiving apparatus, means to energize said sections simultaneously with modulated carrier waves of the same frequency and means for producing a phase relation between the waves traversing successive ones of said sections that is optimum with respect to said receiving apparatus.

2. In a system for communicating with a moving vehicle, a plurality of wave transmission circuits extending along the path of travel thereof, means for energizing successive ones of said circuits simultaneously with carrier waves of equal frequency modulated with a common signaling wave, signaling apparatus on said vehicle, the propagation characteristics of said circuits being so related that said modulated waves transmitted from adjacent portions of said successive circuits are of such relative phases as to reinforce each other in their effect on said signaling apparatus on said vehicle.

3. In a system for communicating with a moving vehicle, a signaling line parallel to the path of travel of said vehicle, said line being divided into a plurality of signaling sections, means to energize said sections simultaneously with signaling waves of the same frequency, the propagation constants of said sections being so related that the signaling waves at adjacent terminals of said sections are similar in amplitude and phase whereby sudden changes in signal level are avoided on said vehicle when said vehicle passes said section terminals.

4. A combination in accordance with claim 3 including means to adjust the phases of the waves traversing said sections.

5. In combination in a system for communicating with a moving vehicle, a high frequency wave transmission line comprising a plurality of sections parallel to the path of said vehicle, modulating and demodulating means associated with each of said sections, said means being connected to a common signal channel, and phase adjusting means in each of said sections to synchronize the high frequency waves at a terminal thereof with similar waves at the terminal of an adjacent section.

6. In a system for communicating with a moving vehicle, a transmission line comprising a plurality of sections distributed along the path of said vehicle, modulating and demodulating means associated with each of said sections, means to supply said last mentioned means with common signal waves and with carrier waves of common frequency and constant relative phases, and means to adjust the relative phases of signals traversing said sections of said transmission line.

7. In a system for communicating between a terminal station and a moving vehicle, a transmission line divided into a plurality of wave transmission circuits paralel to the path of said vehicle, modulating and demodulating means individual to said transmission circuits, a low-frequency signal channel associating said means with said terminal station, means to equalize the time of transmission of signals between said terminal station and a plurality of said modulating and demodulating means, and means to adjust the relative phases of modulated waves traversing successive ones of said wave transmission circuits.

8. In a system for communicating between a moving vehicle and a pair of terminal stations, a high frequency wave transmission line located along the path of said vehicle and energized in a plurality of sections, modulating and demodulating means associated with each of said sections, a signal channel connecting said terminal stations, means to equalize the times of transmission between one of said terminal stations and

a plurality of said last mentioned means, and alternatively-connected means to equalize the times of transmission between the other of said terminal stations and said modulating and demodulating means.

9. A combination as defined in claim 8 comprising in addition means remotely controlled from said terminal stations selectively to connect said equalizing means in circuit.

10. In a system for communicating with a moving vehicle, a pair of terminal stations, a signal channel therebetween, a plurality of wave transmission circuits distributed along the path of said vehicle, means associating each of said wave transmission circuits with said signal channel comprising a source of high frequency waves and modulating and demodulating means connected thereto, means to supply waves from either of said terminal stations for synchronizing said sources of high frequency waves, means to equalize the times of propagation of signal waves between one of said terminal stations and a plurality of said modulating and demodulating means, means to equalize the times of propagation of signal waves between the other of said terminal stations and said plurality of modulating and demodulating means, and means controlled by said synchronizing waves to connect in circuit the equalizing means appropriate to communication with the station producing said synchronizing waves.

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