

April 18, 1933.

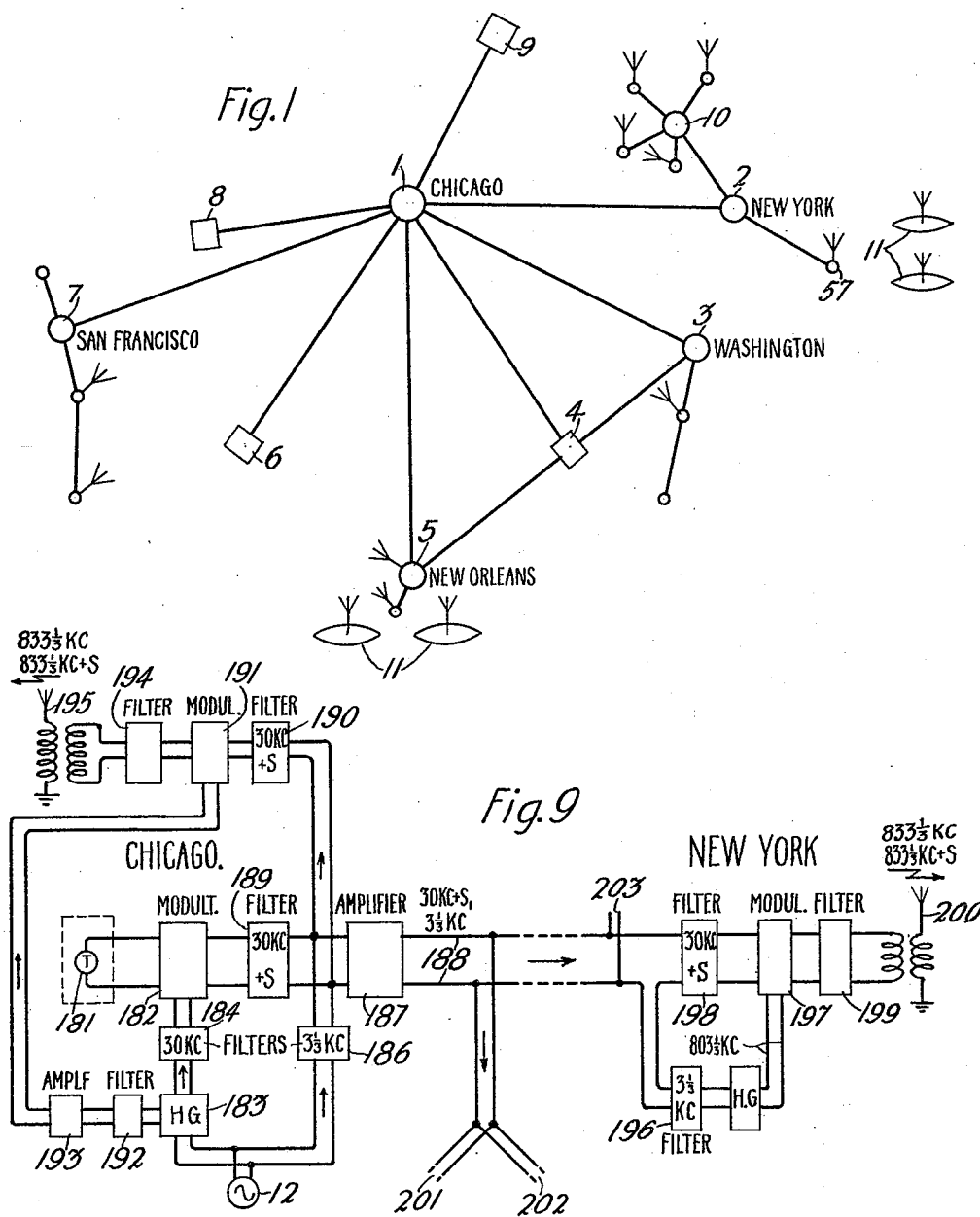
J. W. SCHMIED

1,904,544

CARRIER WAVE SIGNALING SYSTEM

Filed Jan. 31, 1924

8 Sheets-Sheet 1



Inventor:
James W. Schmied
by *E. W. Adams* Atty

April 18, 1933.

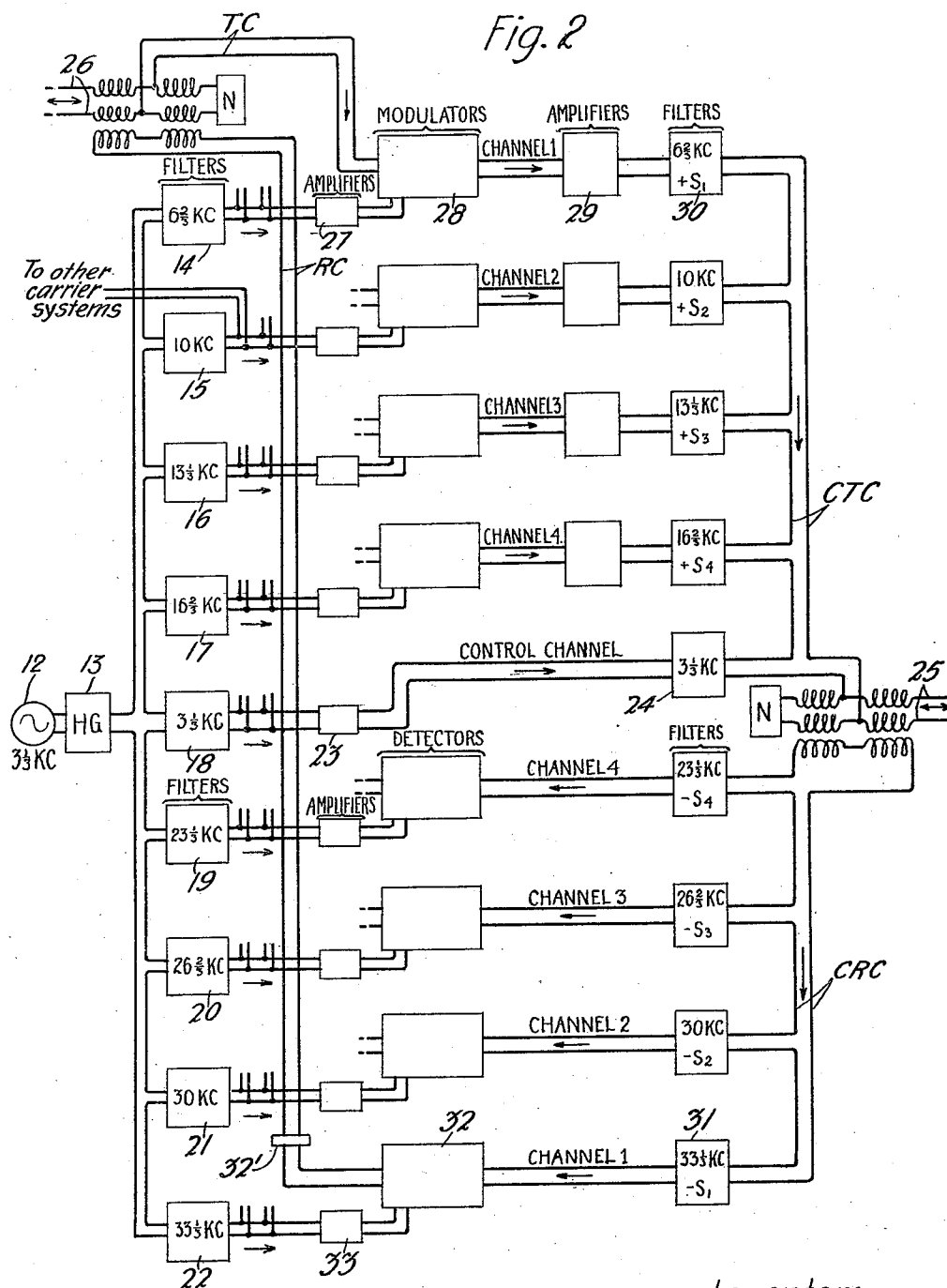
J. W. SCHMIED

1,904,544

CARRIER WAVE SIGNALING SYSTEM

Filed Jan. 31, 1924

8 Sheets-Sheet 2



Inventor:
James W Schmied
by *E. W. Adams* Atty

April 18, 1933.

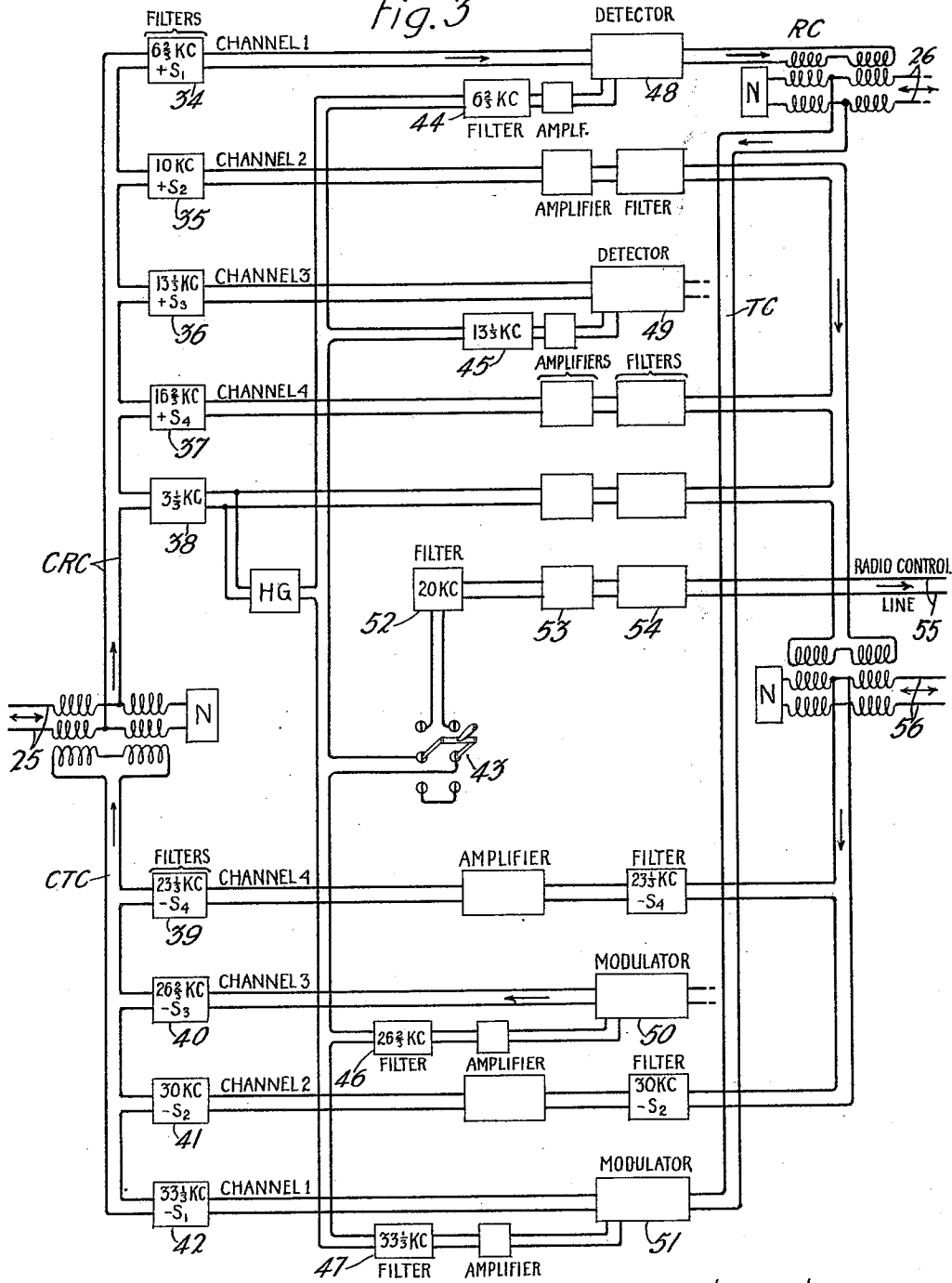
J. W. SCHMIED

1,904,544

CARRIER WAVE SIGNALING SYSTEM

Filed Jan. 31, 1924

8 Sheets-Sheet 3



Inventor:
James W. Schmied
by *E. W. Adams, Atty*

April 18, 1933.

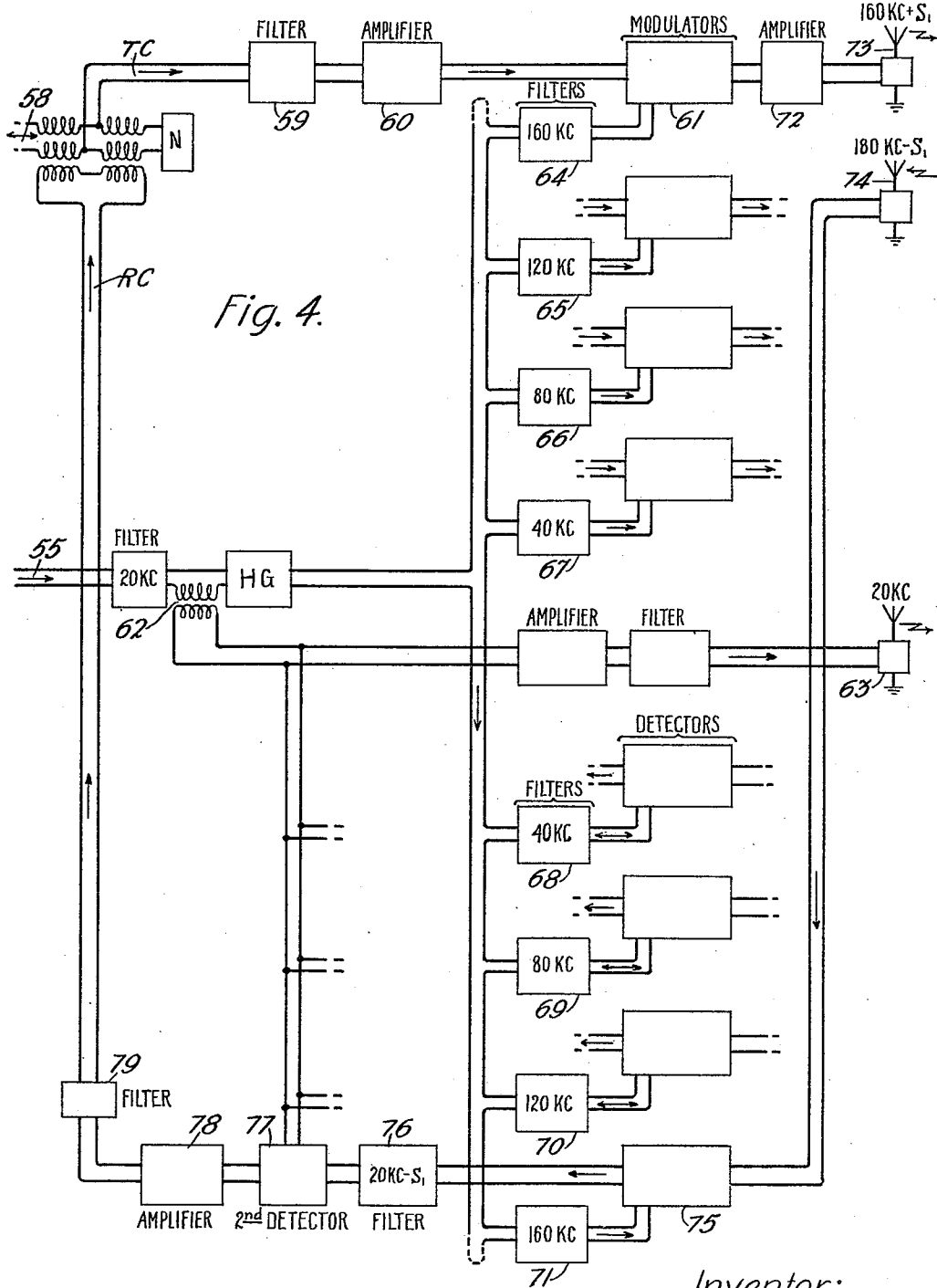
J. W. SCHMIED

1,904,544

CARRIER WAVE SIGNALING SYSTEM

Filed Jan. 31, 1924

8 Sheets-Sheet 4



Inventor:
James W. Schmied
by E. W. Adams, Atty

April 18, 1933.

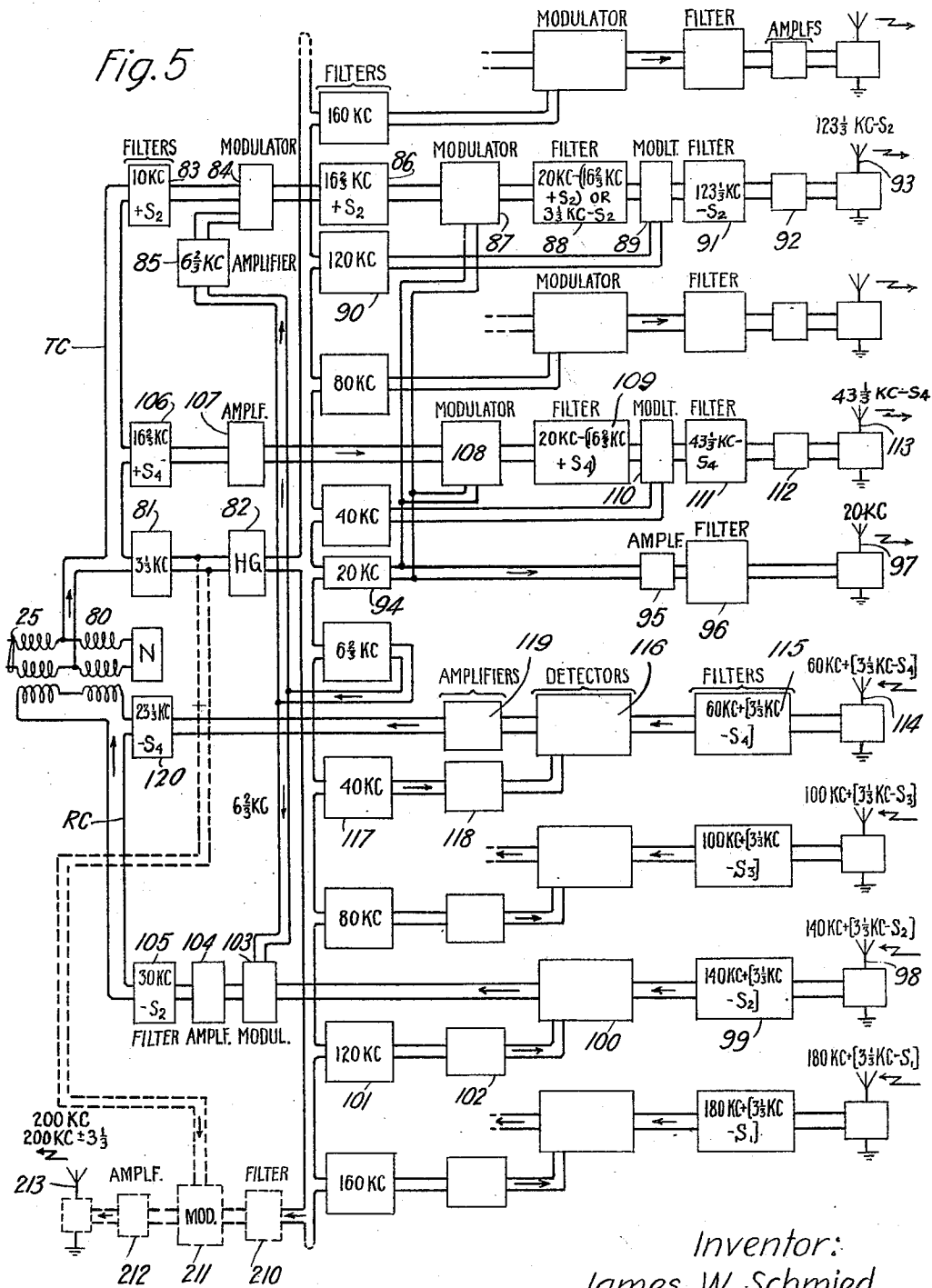
J. W. SCHMIED

1,904,544

CARRIER WAVE SIGNALING SYSTEM

Filed Jan. 31, 1924

8 Sheets-Sheet 5



April 18, 1933.

J. W. SCHMIED

1,904,544

CARRIER WAVE SIGNALING SYSTEM

Filed Jan. 31, 1924

8 Sheets-Sheet 6

Fig. 6

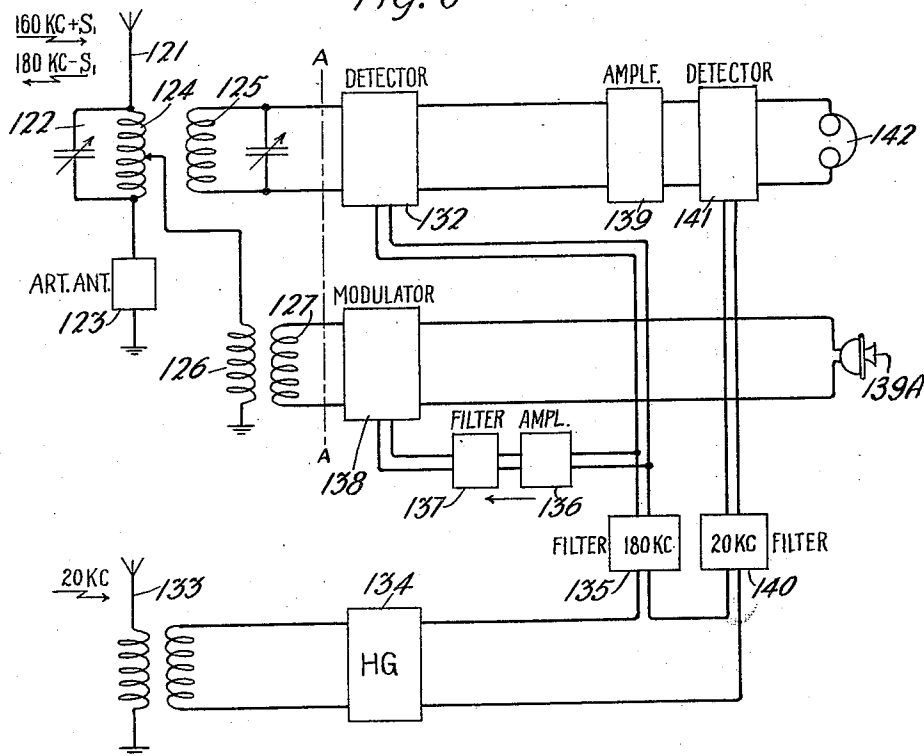


Fig. 6 A

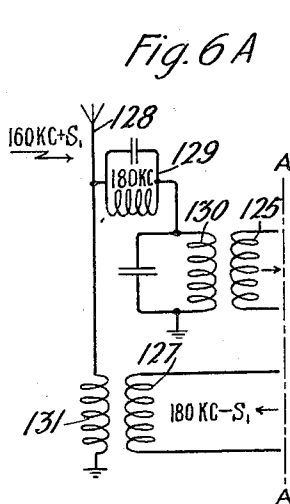
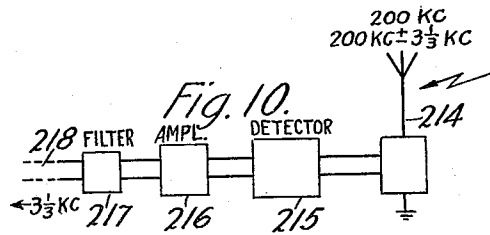


Fig. 10



Inventor:
James W. Schmied
by E. W. Adam Atty

April 18, 1933.

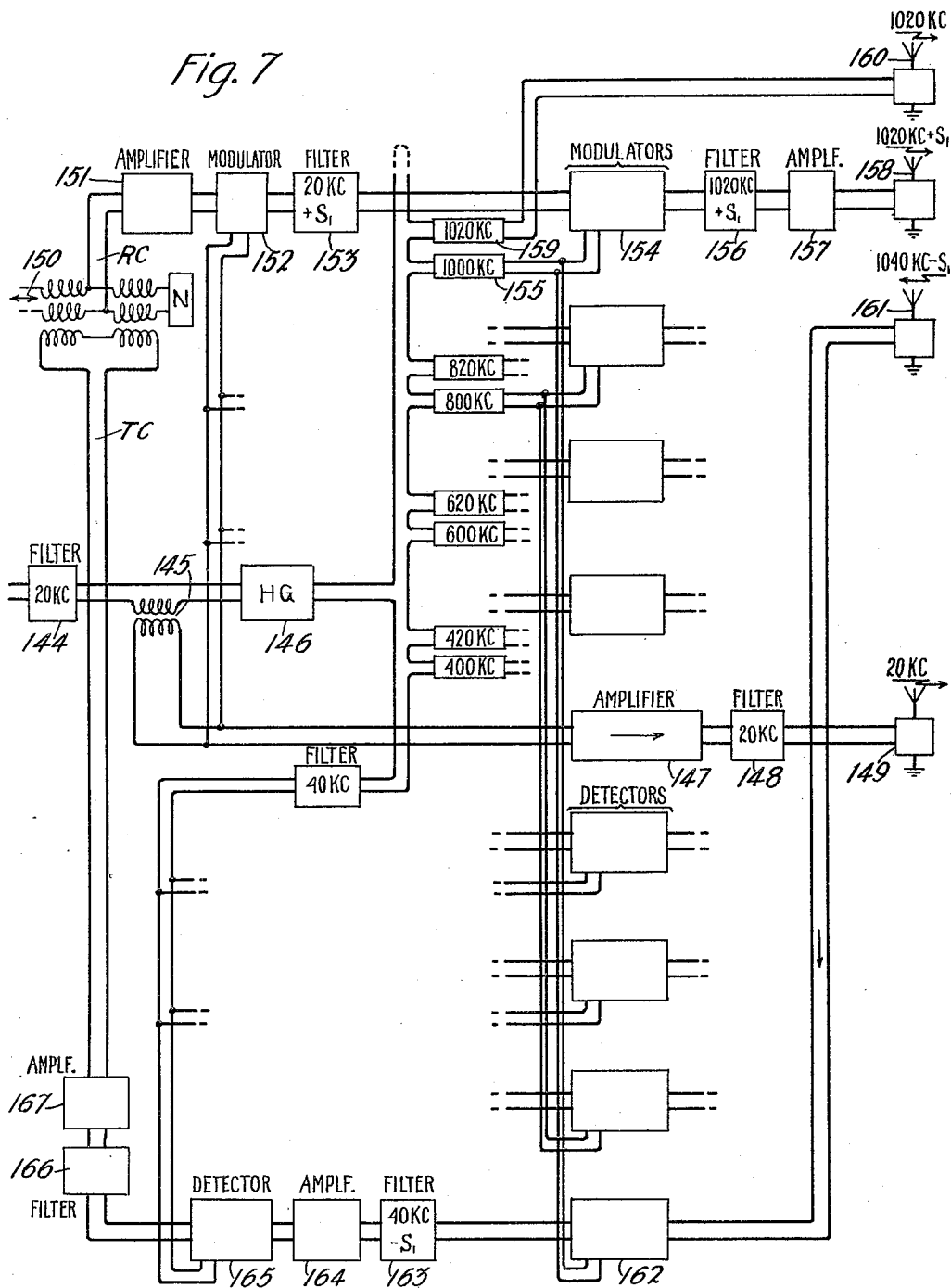
J. W. SCHMIED

1,904,544

CARRIER WAVE SIGNALING SYSTEM

Filed Jan. 31, 1924

8 Sheets-Sheet 7



Inventor:
James W. Schmied
by *E. W. Adams* Atty

April 18, 1933.

J. W. SCHMIED

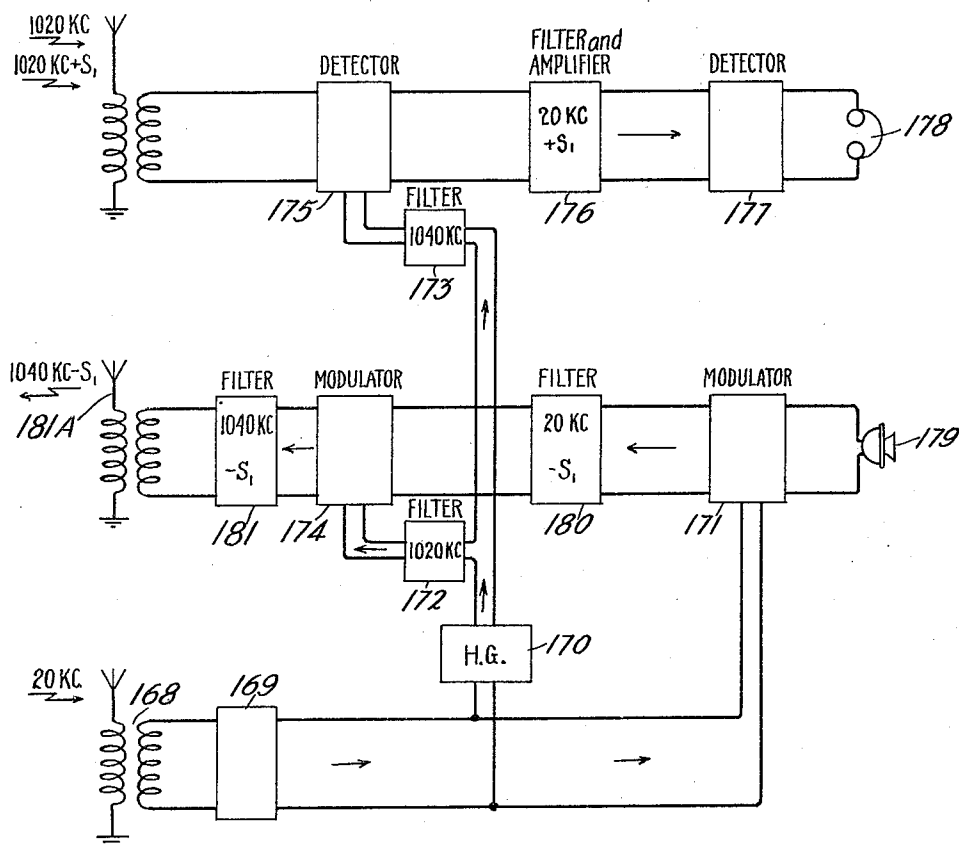
1,904,544

CARRIER WAVE SIGNALING SYSTEM

Filed Jan. 31, 1924

8 Sheets-Sheet 8

Fig. 8



Inventor:
James W. Schmied
by *E. W. Adam* Atty

UNITED STATES PATENT OFFICE

JAMES W. SCHMIED, OF WEST ORANGE, NEW JERSEY, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

CARRIER WAVE SIGNALING SYSTEM

Application filed January 31, 1924. Serial No. 689,627.

This invention relates to carrier signaling and more particularly to a method of and means for controlling the signaling frequencies used by the different stations included in an organization comprising any number of carrier systems.

In a carrier signaling organization comprising a number of systems which are associated and are to be independently operated it is desirable that the frequency range assigned to each system should be relatively fixed. This condition is essential when the organization includes a plurality of radio systems for use in the same district.

Moreover, if one or more of the carrier systems include a number of channels over which signals are to be simultaneously transmitted in two directions, it is necessary, in order to avoid interference, that there should be maintained a definite frequency spacing between all the signal frequencies used in the different channels.

This invention provides an arrangement in which all frequencies used in a number of associated carrier systems, some of which may use wire guided waves and others may utilize free unguided waves, are controlled from a single control or master station, whereby there is prevented any relative shift in the frequency band assigned to the different systems and also any relative change in the frequencies used for the different channels of the several systems.

In accordance with the present invention this result may be secured by generating at a master station and transmitting to the terminal stations of the several systems a fundamental or base frequency from which is derived all the frequencies used on the different systems. More specifically considered the fundamental or base frequency is supplied at the terminal station of each system to a harmonic generator from which different harmonically related frequencies are selected and used for two-way communications over one or more channels between the stations of the system.

The primary object of this invention is to control the frequency relation of the waves

used in a carrier organization comprising a plurality of systems.

A feature of the invention is an arrangement for definitely fixing relatively to each other the frequency bands used in a plurality of associated carrier systems.

Another feature relates to the provision of a single control means whereby a plurality of carrier systems each having one or more channels may be combined to constitute a unitary organization in which a fixed relation for all the frequencies used in the different systems may be maintained.

Still another feature is an organization in which carrier communications may be repeated from wire lines to radio systems.

A still further feature relates to a single control means for all the carrier frequencies used in an organization comprising wire carrier systems and radio systems each having one or more channels.

If the same carrier frequencies are used for a plurality of simultaneous communications in high frequency systems wherein portions of the energy of the carrier wave of one of the channels is effective upon the receiver of another channel and the frequencies are slightly out of synchronism a beat note results which in general is audible. This beat note phenomenon is readily observed in connection with present broadcasting wherein two stations, perhaps many hundreds of miles apart, are using what is, within the limits of measurements, the same wave length, the same frequency. As a matter of fact these are almost always of slightly different frequency and receiving detectors produce a very troublesome, often audible, sometimes inaudible, sometimes rapidly varying beat note. Use of the well known method of carrier suppression may often be advantageous in reducing difficulties of this sort but in the present state of the art 100% suppression of the unmodulated carrier component of a radiated wave is difficult to achieve. The present invention may be applied with or without "carrier suppression" and has for one object to provide and does provide a remedy for "beat note" troubles by insuring throughout a region of any de-

sired extent, that waves theoretically of the same frequency will be actually identical in frequency at all times.

With constantly increasing numbers of carrier channels of long distance telephone and telegraph systems, and radio channels difficulties of the general class arising from improper channel spacing, overlapping signal bands, and unstable carrier wave frequencies tend constantly to increase. The present invention provides means whereby in a unified system many of these difficulties are reduced or entirely remedied.

For a complete understanding of the essential features of this invention reference should be made to the following description of certain embodiments thereof read in connection with the attached drawings of which Fig. 1 is a schematic diagram illustrating an organization of line wire, ship-to-shore, and ship-to-ship channels to which the invention may be applied.

Fig. 2 illustrates a master or control terminal station for a wire carrier system.

Fig. 3 shows one type of terminal station for a wire carrier and radio organization.

Fig. 4 illustrates a radio terminal station for use with the terminal station shown in Fig. 3.

Fig. 5 shows a wire carrier-radio terminal station, which is adapted for application as a shore station of a ship-to-shore system.

Fig. 6 illustrates a terminal radio station, such as a ship station or isolated land station.

Fig. 6—A illustrates an arrangement which may be used in place of the elements shown at the left of the section line AA in Fig. 6.

Fig. 7 illustrates a radio terminal station which may be used in this organization in place of that shown in Fig. 4.

Fig. 8 shows a radio terminal station which may be used with the station shown in Fig. 7.

Fig. 9 shows an organization involving the invention in which messages may be simultaneously transmitted from a plurality of radio terminal stations either on identical wave lengths, as shown, or on different but definitely related wave length, and

Fig. 10 illustrates a radio terminal station for use with the interconnecting channel shown in Fig. 7.

Merely for the purpose of giving a concrete example of an organization in which the invention may be used the schematic diagram shown in Fig. 1 illustrates a carrier network including channels connecting certain places in the northern part of the western hemisphere.

Figure 1

Referring to Fig. 1 there is shown a master control station 1, marked "Chicago",

connected by wire lines with distant terminal stations 2 to 10 inclusive, certain of which are marked "New York", "Washington", "New Orleans", "San Francisco". Stations 2, 3, 5, 7 and 10 are shown as wire terminal stations having radio terminal stations associated with them and remote radio stations 11 adapted to cooperate with the radio stations of 2 and 5 are also shown. The other stations, viz. 1, 4, 6, 8 and 9, are shown as terminal stations for wire systems, but they may also be associated with radio systems. A fundamental feature of the invention is that all carrier frequencies throughout the system are controlled by a source located at any particular station which is selected as the "master control" station.

Fig. 2 illustrates a station adapted to serve as a master control station and as a terminal station which is typical of those used in multiplex wire carrier systems.

Figure 2

The station shown in Fig. 2, adapted for carrier telephony is provided with a source 12, which may be a machine, a space discharge oscillator or other suitable source, for producing a fundamental or control frequency of, for example, three and one third kilocycles, which is supplied to a harmonic generator 13.

The source 12 is maintained at a very constant frequency either by skilled attendants or by means of automatic regulating means now well known to those skilled in the art.

The output circuit of the generator 13 includes devices 14 to 22, which may be tuned circuits or filters, each of which is selective of one of the harmonic frequency components present in the output circuit of the generator.

The device 18 is adapted to select the base frequency which, after being amplified by the device 23, is transmitted through a second selective device 24 to the line 25. This line is connected to the remote terminal of a two-way carrier system and to other systems included in the carrier network.

Devices 14 to 17 inclusive, may be respectively selective of the second, third, fourth and fifth multiples of the base frequency. These multiple frequency waves are used as outgoing carrier waves for the different channels. Devices 19 to 22 inclusive are respectively selective of the seventh, eighth, ninth and tenth multiples of the base frequency. These are used to combine with the respective incoming modulated carrier waves to effect detection.

The operation of the terminal apparatus for each of the channels of each of the wire carrier systems is identical. The following description of the operation of the apparatus for the first channel at the master con-

trol terminal station will therefore serve to set forth the operation of the terminal apparatus for all channels of the several systems included in the organization.

5 A line 26, which may be a telephone line connected directly with a local subscriber or through a local exchange, is adapted to transmit low frequency current to the terminal station and is connected to one pair of
10 terminals of the line windings of a hybrid coil, the opposite terminals of which are connected to a balancing network N. The center taps of the hybrid coil are connected to a local transmitting circuit TC, and the
15 third winding of the hybrid coil is connected to a local receiving circuit RC.

The second multiple of the base frequency, i. e. $6\frac{2}{3}$ kilocycles, which is used as an outgoing carrier current for the first channel is amplified by the device 27 and supplied to the modulator 28. Incoming speech current of frequency S is transmitted over the line 26 and circuit TC to the modulator 28. The carrier and speech currents are combined in the device 28 to produce a modulated carrier current which is amplified by the device 29 and transmitted through the filter 30 and conjugate coupling to the line 25. The line 25 is associated with the carrier channel circuits CTC and CRC by a conjugate connection similar to that described above for the line 26. The filter 30 is designed to select the upper side band of the carrier, i. e. $6\frac{2}{3}$ kilocycles+S, (S being the symbol commonly used to designate the frequencies of speech waves) and to suppress both the carrier component and lower side band, whereby only the upper side band is transmitted over the line 25.

40 The incoming carrier frequency for the first channel is the tenth harmonic, i. e. $33\frac{1}{3}$ kilocycles, and the lower side band only is used. (The term "harmonic" is used herein in the sense of multiple frequency, thus tenth harmonic means a frequency of ten times the base frequency.) Thus the frequency of the incoming modulated carrier current is $33\frac{1}{3}$ kilocycles-S.

50 The modulated current received over the line 25 is transmitted through the filter 31 to the demodulator or detector 32 where it is combined with the current of $33\frac{1}{3}$ kilocycles supplied through the filter 22 and amplifier 33 to produce the speech currents
55 which are transmitted over the circuit RC and line 26 to the subscriber. The output of the detector 32 should be connected through a speech current selective means 32' to the line 26.

60 The station just described is that marked Chicago, (1) in Fig. 1 and each of the wire systems radiating from this station will be provided with terminal apparatus similar to that described above. As is indicated
65 by the taps associated with the output sides

of the filters 14 to 22 inclusive, carrier currents of different frequencies may be supplied to the different channels of the several wires systems emanating from the control station. Moreover, the equipment of each
70 of the other stations for the wire systems, the generator 12 being omitted, will be identical with that shown in Fig. 2. It is contemplated that the base frequency of $3\frac{1}{3}$ kilocycles will be generally transmitted so
75 as to be available at all carrier terminals.

Figure 3

Fig. 3 illustrates what may be called a combined station. That is, a station equipped with wire carrier terminal apparatus, through line carrier repeating apparatus, and means whereby a control frequency may be supplied to a radio system. It is therefore typical of an installation which may be
85 used at stations 2, 3, 5 and 7.

The carrier line 25 is conjugate connected to a carrier receiving circuit CRC and a carrier transmitting circuit CTC. The receiving circuit CRC is provided with devices 34, 35, 36, 37 and 38 which respectively
90 select the different channel frequencies incoming over the line 25. Figs. 2 and 3 therefore illustrate the cooperating terminals of a four-channel carrier multiplex system.

Returning to Fig. 3, transmitting circuit CTC includes the devices 39, 40, 41 and 42 which respectively select the modulated carrier waves or, more specifically the side
100 bands, supplied through the different channels to the line 25.

The fundamental or control frequency is selected by the filter 38 which has its output side connected to a harmonic generator HG.
105

The output circuit of the generator HG is completed by a switch 43. With switch 43 in one position the output circuit of the generator is closed to include selective devices 44, 45, 46 and 47. Oscillations of different harmonic frequencies may be supplied through devices 44 and 45 respectively, to the detector 48 and 49. Devices 46 and 47, respectively, supply carrier currents of harmonic frequencies to the modulators 50
115 and 51. When the switch 43 occupies its other position, a filter 52, in addition to filters 44 to 47, is included in the output circuit of the generator HG. Filter 52 selects a harmonic frequency which is amplified by the device 53, again selected by the filter 54 and supplied to a radio control line 55.
120 The device 52 selects a wave of the frequency of 20 kilocycles which, it is important to note, is not used in a signaling channel
125 of the carrier system.

The first and third channels at this station are provided with terminal apparatus, similar to that shown in Fig. 2, for connecting the carrier line 25 to low frequency or tele-
130

phone lines. The first channel is shown conjugately connected to a telephone line 26. Similarly the terminal apparatus for the third channel will be conjugately associated with a second telephone line, but, for the sake of clarity the connecting means has been omitted.

The second and fourth channels are adapted to operate as repeating circuits through which the signal modulated waves incoming over the line 25 may be transmitted over a second carrier line 56 conjugately associated with the repeating apparatus.

Assuming that the station shown in Fig. 3 is New York, the switch 43 is in its lower position, the first and third channels are connected through a telephone exchange to different subscribers and that channels 2 and 4 are connected for repeating over line 56 to station 10, Fig. 1.

Signal modulated waves, or more precisely side bands of, for example, $6\frac{2}{3}$ KC+S, and $13\frac{1}{3}$ KC+S, respectively, received over channels 1 and 3 of line 25 from a distant station will be combined with local oscillations of $6\frac{2}{3}$ KC and $13\frac{1}{3}$ KC, respectively, in the detectors 48 and 49 and the resultant speech currents will be transmitted over different telephone lines to local subscribers. The output circuits of the detectors 48 and 49 should each be provided with selective devices for the speech currents. Carrier modulated waves respectively received over channels 2 and 4 of line 25 will be selected by devices 35 and 37, amplified, again selected and transmitted over line 56 to a distant station, for example 10, Fig. 1, where they may be detected and the signal currents transmitted to local subscribers, or as will appear later, the carrier modulated waves may be used to modulate a radio carrier wave for transmission to a distant radio station.

By throwing the switch 43 to its upper position the filter 52 will be included in the output circuit of the generator HG and, in addition to the functions just described for channels 1 to 4, there is provided a fifth channel through which a wave of a frequency harmonically related to the fundamental frequency may be supplied to the radio control circuit 55. The line 55 may be a channel on any convenient low frequency telephone line if a separate line is not available.

Instead of transmitting the speech currents to a local subscriber, the arrangement shown in Fig. 3 may be associated with a radio system. The New York terminal station may be connected through a radio terminal station 57, Fig. 1, for communication with distant radio stations 11, herein shown, by way of example, as ships at sea. Thus at terminal station 57 the speech currents transmitted over the telephone lines, for ex-

ample 26, etc., or the side bands transmitted over the line 56, may be used to modulate carrier waves of different radio frequencies derived from the 20 KC radio control wave transmitted over the line 55 or over one of the carrier lines.

A terminal station for producing speech modulated radio carrier waves is shown in Fig. 4 and one in which a carrier wave modulated by speech is used to modulate a radio frequency wave is shown in Fig. 5.

Figure 4

Referring now to Fig. 4 there is shown a multiplex radio system. The complete circuit arrangement for only one channel is illustrated, but similar connections will be used for the other channels.

The low frequency line 58, which may extend from a local station or may be one of the telephone lines extending from the station shown in Fig. 3, is conjugately connected to transmitting and receiving circuits TC and RC respectively. The circuit TC is connected through a filter 59 and amplifier 60 to a modulating device 61.

The radio control frequency transmitted over the control line 55 is supplied to the harmonic generator HG and through a transformer 62, to antenna 63 from which it is continuously radiated. The radio control frequency, as indicated on the drawings is 20 kilocycles.

The output circuit of the harmonic generator HG is provided with selective devices or filters 64 to 71. Each of these devices is adapted to sharply select and freely transmit one of the frequencies, harmonically related to the radio control frequency, which are produced by the generator HG. If necessary separate amplifiers are associated with each of the devices 64 to 71.

Although a multiplex radio system is shown, the complete circuits for one channel only are illustrated. Since all of the channels operate in the same manner, except that different frequencies are used in each channel, it is believed that a description of the operation of one channel will suffice to illustrate the operation of the system.

The eighth harmonic or wave of 160 kilocycles frequency is supplied to the device 61 through a filter 64. The low frequency currents and radio carrier wave are combined in the device 61 to produce a modulated carrier wave. The device 61 comprises a combined modulator and filter as is well known in the art, whereby the unmodulated carrier component and one side frequency component are suppressed and the other side frequency component after being amplified by the device 72 is delivered to and radiated from the antenna 73. As indicated, the upper side band, i. e., 160 kilocycles+S₁, is transmitted. The incoming carrier wave for this

channel is herein indicated as the lower side band derived from a carrier of 180 kilocycles, and hence has a frequency of $180 \text{ KC} - S_1$, where S_1 indicates the frequency of the low frequency modulating current.

The received wave of 180 kilocycles— S_1 incident upon the antenna 74 is transmitted to the detector 75 where it is combined with oscillations of 160 kilocycles supplied by the harmonic generator HG through the filter 71. A carrier modulated wave of 20 kilocycles— S_1 is delivered by the detector 75, which may include separate amplifiers, through the filter 76 to a second detector 77. Carrier oscillations of 20 kilocycles are supplied by the transformer 62 to the detector 77. The output of the detector 77 contains a current component of modulating frequency S_1 which, after being amplified by the device 78, is transmitted through the filter 79 selective of the speech frequency current circuit RC and conjugate connection to the line 58.

With the arrangement described above, two-way communication, under the control of the master control station may be maintained with a remote radio station or stations. In a similar manner any number of communications, limited only by practical considerations, may be held between the radio terminal station and remote radio stations.

The radio system shown in Fig. 5 may be associated with a line carrier system to provide a combined line carrier and radio organization.

Two methods of operation are available for direct transmission from a remote line carrier station through a radio terminal station to a distant radio station.

According to the first method, the signal modulated waves received from the line channels are combined with carrier waves of other different frequencies for transmission to a distant radio station and the incoming radio waves carry signal modulated waves corresponding to the channel frequencies of the line system. Thus the frequencies of the different radio waves will be dependent to some extent upon the frequencies used in the line system and hence the radio carrier frequencies will have to be chosen to provide the proper frequency spacing between the incoming and outgoing waves used in the radio system.

While this method is contemplated by the present invention it involves difficulties which are resolved by the second method. These difficulties reside in the uneconomical use of the frequency spectrum unless a complicated spacing system is chosen for the whole radio organization.

According to the second method, which is preferable, the modulated carrier waves received over the line are each stepped up or

down to the same frequency level, are then used to modulate the radio carrier waves of different frequencies, and the incoming radio waves of different frequencies carrying signal modulated waves of a single frequency are transformed into carrier modulated waves corresponding to the different line channels frequencies over which they are transmitted. The frequency spacing between the radio waves is therefore definitely fixed independently of the carrier frequencies used in the line system and hence an economical use of the frequency spectrum is obtained.

Figure 5

The terminal apparatus illustrated in Fig. 5 is adapted to utilize the second method referred to above.

The line 25 is conjugately connected at 80 to the circuits TC and RC. The fundamental frequency transmitted over the line 25 is supplied through a selective device 81 to a harmonic generator 82. The output circuit of which includes the necessary selective means for the frequencies used in radio transmission. The circuits TC and RC are provided with means respectively selective of the different waves used for communication over the line channels.

With reference to channel two, the signal wave of $10 \text{ KC} + S_2$ received over the line is selected by the filter 83 and combined in the modulator 84 with amplified oscillations of $6\frac{2}{3} \text{ KC}$ supplied through the amplifier 85 to produce a modulated wave having a component of $16\frac{2}{3} \text{ KC} + S_2$. This component is selected by the filter 86, supplied to the modulator 87 together with 20 KC oscillations derived from the harmonic generator 82 to produce a modulated wave having a side component of $20 \text{ KC} - (16\frac{2}{3} \text{ KC} + S_2)$ which is selected by the filter 88. The selected component, viz. $3\frac{1}{3} \text{ KC} - S_2$, is impressed upon the modulator 89 together with oscillations of 120 KC transmitted from the generator 82 through the filter 90. The side band of $123\frac{1}{3} \text{ KC} - S_2$ is selected by the filter 91, amplified by the device 92, which preferably includes means selective of the desired side band, and radiated from the antenna 93 to the distant radio station. A control frequency of 20 KC supplied by the generator 82 is selected by the device 94 amplified by the apparatus 95 selected by the filter 96 and continuously radiated from the antenna 97.

Incoming radio signal modulated wave or side bands incoming into channel two, which is assumed to have a carrier frequency of 140 KC modulated by a wave of $3\frac{1}{3} \text{ KC} - S_2$, or $143\frac{1}{3} \text{ KC} - S_2$, is received by the antenna 98, selected and amplified, if desired, by the device 99 and supplied to the detector 100. Oscillations of 120 KC are

also supplied to the detector 100, through the filter 101 and amplifier 102. The received waves and local oscillations are combined in the detector 100 to produce a difference frequency wave of $23\frac{1}{3}$ KC- S_2 . This wave is combined with oscillations of $6\frac{2}{3}$ KC in the modulator 103 amplified by the device 104 and the component of 30 KC- S_2 is selectively transmitted by the filter 105 through the circuit RC to the line 25. (Observe that channel 2 of Fig. 5 corresponds in frequencies and may be used interchangeably with channel 2 of Fig. 2 or 3).

The signal waves received over the fourth channel of the line 25, of frequency $16\frac{2}{3}$ KC+ S_4 , are selected by the filter 106, amplified by the device 107, and combined in the modulator 108 with oscillations of 20 KC supplied by the harmonic producer 82 through the filter 94.

The component 20 KC-($16\frac{2}{3}$ KC+ S_4) or $3\frac{1}{3}$ KC- S_4 , resulting from the combination of the incoming waves and the local oscillations, is selected by the filter 109 and combined in the modulator 110 with a carrier wave of 40 KC. The upper side frequency 40 KC+ $3\frac{1}{3}$ KC- S_4 or $43\frac{1}{3}$ KC- S_4 is selected by the filter 111, amplified by device 112, which preferably should include selecting means for the upper side frequency and supplied to the antenna 113 for radiation to a distant station.

The incoming radio wave for the fourth channel, of 60 KC carrier frequency modulated by a wave of $3\frac{1}{3}$ KC- S_4 , or $63\frac{1}{3}$ KC- S_4 , incident upon the antenna 114 is selected, and if desired, amplified, in the apparatus 115 and supplied to the detector 116.

Oscillations of 40 KC derived from the generator 82, selected by the filter 117 and amplified by 118, are supplied to the detector 116. The resultant output wave components are amplified by the device 119 and the component of $23\frac{1}{3}$ KC- S_4 , which corresponds to that of the fourth line channel, is selected by the filter 120 and transmitted through the circuit RC, conjugate connection 80, and over the line 25 to the distant line terminal station.

A four channel organization is indicated, but obviously the number of channels may be increased to the maximum possible for the frequency range available. Each of the channels will be operated in a manner similar to that described above for channels two and four.

It is to be noted that all side bands radiated by, or received into the system of Fig. 5, are inverted and displaced relatively to the nearest carrier frequency which can be derived from the base frequency of 20 KC. Consequently these side bands cannot be received by means of a carrier wave which is a multiple of 20 KC unless a component of

$3\frac{1}{3}$ KC or one of the multiples thereof is also present.

It is to be understood that, wherever essential for efficient operation, the incoming and outgoing circuits of the different channels shown in Fig. 5, may include amplifying and selective means. This may be done by including the amplifying and selective devices in the different apparatus units shown, or by using separate units connected into the circuits.

In the organization shown in Fig. 5 a series of modulated waves, arriving over one series of channels having a fixed frequency spacing, are repeated as modulated waves of other frequencies over a second series of channels having a different but constant frequency spacing between them. This organization therefore provides for through repeating from one carrier system to a second carrier system, in which each system uses a series of waves of different frequencies uniformly spaced.

In this system a series of waves uniformly spaced apart and having one energy level may be transformed into a series of waves having a different uniform spacing and energy level, whereby carrier systems which are respectively efficient for short and long distance transmission or for low carrier wave and high carrier wave frequencies may be associated for joint operation.

A complete system might comprise a channel extending from line 26 (Fig. 2), through a channel of Fig. 2, line 25, a channel of Fig. 5, and into a radio channel connecting with a similar system at the distant terminal. In no part of such a system between the low frequency lines would the signal waves be of the normal frequency of speech or capable of detection by a simple receiver.

Fig. 6 illustrates a radio station for use in a system having a terminal station adapted to transmit a carrier wave modulated by signal currents, the upper side frequency only being radiated. A terminal station of this type is shown in Fig. 4.

Figures 6 and 6-A

In Fig. 6, representing a ship station or other isolated radio station, the antenna system including an antenna 121 is connected through a coupling circuit 122 and an artificial antenna or balancing network 123 to ground. The coupling circuit 122 is tuned broadly to select the incoming and outgoing waves used at this station and is conjugately associated with the transmitting and receiving circuits. The receiving circuit is inductively coupled to the antenna system by the coils 124 and 125. A circuit extending from the midpoint of the coil 124 to ground and including the coil 126 is associated with the transmitting circuit by the

inductive coupling between the coil 126 and the coil 127.

Fig. 6—A illustrates an antenna system and means for coupling the transmitting and receiving circuits of a radio station which is slightly different from that shown in the preceding figure. This arrangement may be substituted for that portion of Fig. 6 which lies to the left of the section line 10 AA.

In Fig. 6—A the antenna system comprises the antenna 128 having two paths to ground, one of which includes a trap circuit 129 and a circuit tuned to the incoming waves 130. The second path includes a coil 131. The receiving apparatus is associated with the antenna system by the inductive coupling between the circuit 130 and the coil 125 and the coil 131 is inductively associated with the coil 127 included in the transmitting circuit. The trap circuit 129 is resonant to the transmitted carrier frequency and is designed to permit a limited amount of energy of this frequency to be supplied from the antenna circuit to the receiving circuit, for a purpose to be described later.

According to the system shown in Fig. 6, the incoming signal wave incident upon the antenna 121 is transferred to the detector 132 through the coupling transformer 124—125.

The radio control frequency of 20 KC incident upon the antenna 133 is supplied to the generator 134, adapted to produce oscillations of different frequencies harmonically related to the control frequency.

The generator 134 supplies oscillations of the desired frequencies for both transmission and reception.

In the example illustrated a component of 180 KC is selected by the filter 135 amplified by the device 136 and transmitted through the filter 137 to the modulator 138 to constitute the carrier wave for outgoing messages. The device 138 may comprise any well known system for producing a modulated high frequency wave including, or having associated with it, means for suppressing the carrier component and one side band component and for supplying the other side band component to the antenna. The device 138A which may be a telephone transmitter or other similar device for supplying modulating current to the device 138. Assuming that the frequency of the current supplied by the device 139 A is S_1 and the lower side band is used, the frequency of the transmitted radio wave will be $180 \text{ KC} - S_1$. The modulator may comprise apparatus for wholly or partly suppressing one side band and the carrier, or for radiating all the components of the modulated wave.

Let it be assumed that the corresponding

carrier signal wave to be received from a distant station by the antenna 121 is $160 \text{ KC} + S_1$. These waves are transmitted substantially without attenuation through the coupling circuit 122 and are supplied through the coupling 124—125 to the detector 132 which is also supplied with oscillations of 180 KC through the filter 135. The received waves and local oscillations are combined in the detector 132, to produce an intermediate frequency modulated wave of $20 \text{ KC} + S_1$, which is selectively amplified by the device 139. The selected wave and local oscillations of 20 KC transmitted from the generator 134 through the filter 140 are supplied to and combined in the detector 141 to yield the signal current of frequency S_1 , which are impressed upon the receiving device 142, shown, by way of example, as a telephone receiver.

Instead of supplying local oscillations for the first stage of detection through the filter 135 to the detector 132, the system may be designed to supply a certain amount of the outgoing energy of carrier frequency from the antenna circuit to the receiver circuit. This may be accomplished by providing a certain amount of unbalance in the connection for coupling the transmitting and receiving circuits to the antenna circuit.

An arrangement for supplying the necessary energy of outgoing carrier frequency from the antenna circuit to the input circuit of the first detector is shown in Fig. 6—A.

The carrier wave of 180 KC is supplied through the coupling 127—131 to the antenna circuit, whence it is transmitted through the trap circuit 129 and circuit 130 to the coil 125 included in the input circuit of the detector 132. The incoming signal wave of $160 \text{ KC} + S_1$ incident upon the antenna will be transmitted through the trap circuit 129, circuit 130 to ground. Due to the coupling between coils 130 and 125 energy of the incoming wave of signal frequency, $160 \text{ KC} + S_1$, and the outgoing wave of carrier frequency, 180 KC, traversing the antenna circuit will be supplied to the input electrodes of the detector 132. The signal waves and local oscillations will be combined in the detector to produce an intermediate frequency modulated wave of $20 \text{ KC} + S_1$ which will then be amplified and combined with oscillations of 20 KC in the device 141 to yield the signal current.

A characteristic feature of the invention is that ship stations or other remote or isolated stations may communicate with each other as well as the radio terminals associated with the wire line systems. Any of the isolated stations may communicate with other isolated stations not controlled as a part of a system in accordance with the invention provided only that the other isolated

stations are provided with wave sources of a suitable frequency or frequencies.

Figures 7 and 8

5 Figs. 7 and 8 illustrate a radio system adapted for use in a line carrier-radio organization. In this arrangement an unmodulated carrier wave, a modulated carrier wave, and a wave of control frequency are
10 radiated from a radio terminal station. In the receiving circuit at the distant radio station oscillations derived from the control wave are used to combine with the received modulated and unmodulated waves to provide the currents of different frequencies required for effecting successive detection of the incoming signal waves. At the terminal station the receiving arrangement includes a successive detection system which is supplied with combining oscillations derived from the wave of control frequency by a harmonic generator.

Figure 7

25 Referring to Fig. 7, there is shown a terminal station for multiplex radio operation.

A radio control wave of 20 KC is transmitted through a filter 144 from a line carrier system to a radio circuit including a
30 transformer 145 and harmonic generator 146. The transformer supplies the control wave through an amplifier 147 and filter 148 to an antenna 149 from which it is continuously radiated. The output circuit of the
35 generator 146 includes the necessary selective devices or filters for the different frequencies used for two-way radio communications over a number of channels. As stated above, a successive detection receiving system is used.

40 Since all of the channels utilize the same principles, it is believed that the functions of the different elements constituting the radio terminal apparatus will be clear from the following description of the operation of one channel. The frequencies used in the several channels will, of course, be different.

Low frequency currents, for example speech currents, are transmitted over the
50 line 150 which is conjugately connected through the circuits RC and TC to the radio apparatus.

The low frequency energy received from a distant station over the line 150 is amplified by the device 151 and supplied to a modulator 152. A carrier wave of 20 KC is also supplied to the modulator. The low frequency current and carrier wave are combined to produce a carrier modulated wave
60 the upper side band of which, or $20 \text{ KC} + S_1$, is selectively transmitted through the filter 153 to a modulator 154 to which the generator 146 supplies a carrier wave of 1,000 KC through the filter 155. The modulated carrier wave of 1,020 $\text{KC} + S_1$ resulting from

the operation of the device 154, is selected by the filter 156, amplified by 157, and radiated from the antenna 158.

The harmonic generator 146 supplies a wave of 1,020 KC through the selective means 159 to an antenna 160 from which it is radiated. 70

Incoming carrier signal modulated waves of say 1,040 $\text{KC} - S_1$ incident upon the antenna 161 at this station are combined with oscillations of 1,000 KC, supplied by the generator 146, in the detector 162. The side component of 40 $\text{KC} - S_1$, thereby produced, is transmitted through the filter 163, amplified by the device 164 and combined in the detector 165 with oscillations of 40 KC supplied by the generator 146 to yield the low frequency signal currents. The filter 166 selects the low frequency currents which are then amplified by the device 167 and transmitted over the circuit TC and line 150 to the subscriber. 85

Figure 8

As shown in Fig. 8, which may represent 90 the circuit of a ship station or other isolated radio station, the incoming control wave of 20 KC incident upon the antenna 168 is transmitted by the selective means 169 to a harmonic generator 170 and also to a modulator 171. The generator 170 supplies components harmonically related to the control frequency through selective devices 172 and 173 respectively, to a modulator 174 and a detector 175. 95

In this system, the incoming unmodulated carrier waves of 1,020 KC, the modulated carrier of 1,020 $\text{KC} + S_1$, and 1,040 KC are supplied to the detector 175 in which they are combined. The components of 20
100 $\text{KC} + S_1$, and 20 KC resulting from combining the two incoming waves with the 1,040 KC oscillations supplied by the generator are selected and amplified by the device 176. The amplified energy is supplied to and
105 combined in the detector 177 to yield the low frequency signal current which is used to actuate the receiver 178, herein shown as a telephone receiver. 110

Signaling currents are supplied by the device 179, for example a telephone transmitter, to the modulator 171 wherein they are combined with a wave of 20 KC received from the selective device 169. 115

The lower side frequency component, or $20 \text{ KC} - S_1$ is selected by the filter 180 and transmitted to the modulator 174, in which it is combined with a high frequency wave of 1,020 KC supplied by the generator 170 through the filter 172. The resultant lower side frequency component of 1,040 $\text{KC} - S_1$ is selected by the filter 181, transmitted to the antenna 181A and radiated to a distant station. This may be a terminal station, 120

similar to that shown in Fig. 7, or any other remote station.

In the circuits of Figs. 7 and 8, it is to be understood that separate amplifiers may be used wherever they are necessary to efficient operation.

Figure 9

Fig. 9 illustrates a line carrier and radio combination involving the invention, which may be used for broadcasting or transmitting for other purposes simultaneously from widely separated radio stations on the same wave length.

In Fig. 9 there are shown two radio broadcasting stations, for example one at Chicago and the other at New York connected by a carrier line. Additional circuits are connected to the carrier line to indicate that the connection may be extended to any number of additional radio broadcasting stations.

Let it be assumed that the studio is situated at Chicago. The message or entertainment to be broadcasted is supplied by the transmitter 181 to a modulator 182, also supplied with a carrier wave by a harmonic generator 183, through a filter 184. A source 12 which may be the master oscillator indicated in Fig. 2 or another source, if desired, supplies the fundamental frequency to the harmonic generator 183. The fundamental frequency, as in the systems previously described, may be $3\frac{1}{3}$ KC and is transmitted through the filter 186 to the device 187, which supplies amplified energy of the base frequency to the carrier line 188.

A carrier wave of 30 KC is transmitted through the filter 184 to the modulator 182 where it is combined with the message currents of, for example, frequency S received from the transmitter 181, to produce a modulated carrier wave. The upper side frequency of 30 KC+S is selected by the filter 189 and transmitted simultaneously to the local radio broadcasting station, and after being amplified by the device 187, over the line 188 to the distant station or stations. The channel 30 KC+S is assumed to be a high quality channel such as will transmit the entire range of frequencies involved by varying "S" over a range of 5,000 cycles to zero.

At the local radio station the modulated wave 30 KC+S is transmitted through the filter 190 to the modulator 191. The filter 190 serves to transmit the 30 KC+S wave substantially without attenuation and to prevent the flow of the fundamental frequency to the modulator 191. A carrier wave of $803\frac{1}{3}$ KC, produced by the generator 183, is transmitted through a filter 192, amplified by the device 193 and supplied to the modulator 191.

The modulated wave of 30 KC+S and the wave of $803\frac{1}{3}$ KC are combined in the mod-

ulator. The upper side band of $833\frac{1}{3}$ KC+S and the unmodulated carrier of $833\frac{1}{3}$ KC are transmitted through the filter 194 to the antenna 195.

At the New York station the fundamental frequency selected by the filter 196 is supplied to a harmonic generator adapted to supply a component of $803\frac{1}{3}$ KC to a modulator 197 to which the modulated wave of 30 KC+S, incoming over line 188, is selected by the filter 198.

The modulated wave of 30 KC+S and the component of $833\frac{1}{3}$ KC are combined in the modulator 197, the upper side frequency of $833\frac{1}{3}$ KC+S and unmodulated carrier of $803\frac{1}{3}$ are transmitted through the filter 199 and radiated from the antenna 200.

The modulated line carrier wave 30 KC+S, and a wave of the fundamental frequency $3\frac{1}{3}$ KC may be transmitted over other lines, such as 201, 202 and 203, of which there may be any number, to similar radio broadcasting stations.

The studio may be situated at any of the stations and by using a plurality of channels associated with the lines different messages or entertainments originating at one or more of the stations may be broadcasted from one or more stations of the system. Moreover, the channel described above may be one of a multiplex carrier system, such as that of Fig. 2, in which the other channels are used to carry commercial traffic.

With the system just described, the broadcast program may be radiated from a plurality of stations situated at geographical or commercial centers of a country or continent on a wave length which is absolutely the same, the emission, except for the short interval necessary for transmission from the point of origin to the point of radiation, will be simultaneous, and both the line and radio carrier waves, being derived from the same fundamental frequency, will be kept in synchronism at all times. The several radiations will not interfere, but on the contrary will aid each other and hence, for a listener at an intermediate point, it is immaterial whether the energy received by him is derived from one or more or all of the radiating stations. It will be observed that the frequency of $833\frac{1}{3}$ KC corresponds to the 360 meter wave length widely used in broadcasting and other wave lengths differing by units of $3\frac{1}{3}$, $6\frac{2}{3}$, 10 or $13\frac{1}{3}$ KC may readily be used.

Figures 5 and 10

Referring now to Fig. 5 there is shown, in dotted line, a channel for extending the system to distant geographical entities for example to the other continents or islands or systems on the same continent not connected by wire lines.

The filter 210 selects a carrier wave of

say 200 KC and transmits it to a modulator 211 which is also supplied with energy of the base frequency, $3\frac{1}{3}$ KC. The carrier and base frequency waves are combined in the modulator 211 to produce a modulated wave of $200 \text{ KC} \pm 3\frac{1}{3} \text{ KC}$ which, together with the unmodulated carrier wave component of 200 KC is supplied to and amplified by the device 212. The amplified modulated and unmodulated components are supplied to and radiated from the antenna 213.

At a distant island or continent a radio receiving system similar to that shown in Fig. 10 is used. The incoming modulated side band components and the unmodulated carrier component incident upon the antenna 214 are supplied to and combined in the detector 215 to yield the wave of base frequency $3\frac{1}{3}$ KC, which is selected and amplified by the device 216. The amplified wave of base frequency is transmitted through a selective device or filter 217 and a line 218 to a harmonic generator 13 included in a terminal control station similar to that shown in Fig. 2.

By duplicating the arrangements hereinbefore described and combining them to supply line carrier and radio systems, a carrier signaling organization having the desired characteristic may be provided for a second geographical entity, the frequencies used in the different systems of this second organization will be determined by the generator 13 at station 1 of Fig. 1. In like manner, carrier organizations for several different entities and in fact for any number of systems on the same or different continents may be interconnected to constitute a universal combination having all the frequencies used therein controlled from a single master control station.

The master oscillator which controls the entire system should be maintained by appropriate means in constant operation and at as constant a frequency as possible. Substitutes may be provided with means for switching them automatically or manually into circuit if the oscillator ceases to function normally. Furthermore it is contemplated that alternative channels to as many carrier terminal points as possible be provided. Thus the station 5 (Fig. 1) may receive its frequency setting oscillations of $3\frac{1}{3}$ KC directly from station 1 or indirectly via station 3 or station 4. Furthermore it is contemplated that any carrier system becoming disconnected by accident or otherwise from the master oscillator source 12 may by a simple emergency arrangement of a radio receiver such as that of Fig. 10 receive the standard frequency wave of $3\frac{1}{3}$ KC if such mode of operation is deemed desirable and if such apparatus as the dotted line portion of Fig. 5 is functioning.

The standard 20 KC radio frequency is

radiated from as many separate points and with such power as may be necessary to keep all radio stations supplied with sufficient frequency setting energy of the desired frequency.

This invention contemplates a carrier organization in which may be included any number of line carrier systems, each having one or more channels, and any number of radio systems, each having one or more channels whether adapted for independent operation or cooperatively associated and having the frequencies used in the different systems as well as each of the channels thereof held in absolute synchronism.

The principles of the invention are independent of the type of apparatus used in the various systems, i. e. amplifiers, modulators or modulating apparatus, selective devices, and sources of carrier waves or signal currents. Moreover, each system may utilize the well known principles of operation peculiar to their respective types, whether used for telegraph, telephone or other signal transmissions, or for control purposes.

While several different arrangements have been described for the purpose of clearly and completely disclosing the nature of the invention, it is to be understood that this invention may be embodied in many different modifications without departing from its principles, and hence that it is not to be limited to the specific features and arrangements described but only by the scope of the attached claims.

What is claimed is:

1. In a communicating arrangement embodying line carrier systems and one or more radio systems, the method of operating the arrangement which comprises supplying a wave of given frequency, controlling the frequencies of the carrier waves for the line systems and a radio control wave by said wave of given frequency, and controlling the frequencies of the radio carrier waves by said wave of radio control frequency.

2. In a communicating arrangement a line carrier system, and a radio system co-operatively associated, means for supplying a wave of given frequency to said arrangement, means for controlling by said wave of given frequency the frequencies of the carrier waves for said line system and a control wave for said radio system, and means for controlling by said control wave the frequencies of the carrier waves for said radio system.

3. In a communicating arrangement a line carrier system and a radio system co-operatively associated, means for supplying a wave of given frequency to said arrangement, means for controlling by said wave of given frequency the frequencies of the

carrier waves for said line system and a control wave for said radio system, and means for controlling by said control wave the frequencies of the waves used for transmission and the oscillations used for successive detection receiving systems included in said radio system.

4. The method which comprises fixing and maintaining line wire channels of a plural channel signaling system with a given frequency separation and maintaining one or more sets of radio channels with a frequency separation which is an exact multiple of that used for the line wire channels.

5. The method of controlling signaling wave frequencies which comprises maintaining carrier line channels over a given region spaced by a constant amount and maintaining radio channels over the region spaced by a constant multiple thereof.

6. The method of radio transmission which comprises supplying to a plurality of stations a wave of given frequency to control at each station the production of a radio carrier wave of single frequency, modulating the carrier waves by the same message, and radiating the modulated waves.

7. A radio system comprising a plurality of transmitting stations, means for supplying to said stations a wave of given frequency for controlling at each of said stations the production of a radio carrier wave of the same frequency, and means at each station for modulating said radio wave by the same message and for radiating said modulated waves.

8. A line-wire-carrier and radio organization having a fixed spacing of carrier channels, and means whereby waves of frequencies which are multiples of the spacing frequency value are employed as line-radio translating waves at line-radio junction points.

9. In combination, a plurality of radio transmitting stations, means individual to each of the stations for applying signal variations to the wave transmitted therefrom, and means, including a generator of low-frequency oscillations, for maintaining a definite frequency relation between the carrier waves transmitted from said stations.

10. In combination, a plurality of radio transmitting stations separated geographically a distance independent of the radiated wave length, a control-frequency channel linking said stations, and means associated with said control channel for generating low-frequency oscillations.

11. In combination, a plurality of radio transmitting stations, a control frequency channel linking said stations, means for generating a control-frequency, means at each station for deriving a radiation frequency from said control frequency and means for

supplying to each station a modulation frequency from a common source.

12. In combination, a plurality of radio transmitting stations, a control-frequency channel linking said stations, means for generating a control-frequency associated with said control-frequency channel, means for impressing audio-frequency potentials on said channel, means at certain of said stations for deriving a high frequency from said control frequency, and means whereby said audio-frequency may be employed to modulate said high frequency.

13. In combination, a plurality of transmitting stations each operating at a different frequency, certain of said stations comprising means for deriving a high-frequency oscillating current from a audible-frequency control-current, means for generating and supplying to certain of said stations a control-current, and means at certain of said stations for amplifying the said derived high frequency.

14. A radio transmission comprising a master control station and a plurality of radio transmitting stations, means at the control station for generating a line wire carrier wave, means comprising line wires for transmitting the carrier wave to each radio transmitting station, means at each of the radio transmitting stations for increasing to the same degree the frequency of the line wire carrier wave to produce at each station a radio carrier wave of comparatively high frequency relatively to that of the line carrier wave, means at the master control station for generating a wave of signal frequency, means comprising line wires for transmitting the signal frequency wave to each radio transmitting station, and means at each radio transmitting station for modulating the radio carrier wave by the signal frequency wave.

15. A radio transmission system comprising a master control station and a plurality of radio transmitting stations, means at the control station for generating a line wire carrier wave, means comprising line wires for transmitting the carrier wave to each radio transmitting station, distortion means at each of the radio transmitting stations for producing harmonics of the line carrier wave, means at each of the radio transmitting stations for increasing the frequency of said wave to the same degree to produce at each station a radio carrier wave of comparatively high frequency relatively to that of the line carrier wave by filtering out a desired harmonic of the line carrier wave, means at the master control station for generating a wave of signal frequency, means comprising line wires for transmitting the signal frequency wave to each radio transmitting station, and means at each radio transmitting station for mod-

ulating the radio carrier wave by the signal frequency wave.

16. In combination, a plurality of radio transmitting stations, a control frequency channel linking said stations, means for generating a control frequency associated with said control frequency channel, means for impressing on said channel potentials varying at audio-frequency, means at certain of said stations for deriving a high frequency from said control frequency, and means whereby said audio-frequency variations may be employed to modulate said high frequency.

17. The method of radio transmission which comprises generating a carrier wave at a master control station, transmitting the carrier wave over line wires to a plurality of radio transmitting stations, changing the frequency of the line wire carrier wave to the same degree at each of the transmitting stations to produce at each station a radio carrier wave of frequency high relatively to that of the line wire carrier wave, and modulating the radio carrier wave at each radio transmitting station by a wave varying in accordance with signals generated at said master control station.

18. The method of radio transmission which comprises generating at a master control station a carrier wave of such frequency that a given harmonic of said wave will be of a desired radio frequency, transmitting the carrier wave over line wires to a plurality of radio transmitting stations, distorting the wave at each transmitting station to produce harmonics of said wave, increasing the frequency of the carrier wave to the same degree at each of the transmitting stations to produce at each station a radio carrier wave of frequency comparatively high relatively to that of the line carrier wave by filtering out the desired harmonic of the line wire carrier wave, and modulating the radio carrier wave at each radio transmitting station by a wave varying in accordance with signals generated at said master control station.

19. A radio transmission system comprising a master control station and a plurality of radio transmitting stations, means at the master control station for generating a line carrier wave, means comprising line wires for transmitting the carrier wave to each radio transmitting station, means at each of the radio transmitting stations for increasing to the same degree the frequency of the line wire carrier wave to produce at each station a radio carrier wave of comparatively high frequency relatively to that of the line carrier wave, means at the master control station for generating a wave varying in accordance with signals, means comprising line wires for transmitting the signal variations to each radio transmitting sta-

tion, and means at each radio transmitting station for modulating the radio carrier wave by the signal variations.

20. A radio transmission system comprising a master control station and a plurality of radio transmitting stations, means at the control station for generating a line wire carrier wave, means comprising line wires for transmitting the carrier wave to each radio transmitting station, distorting means at each of the radio transmitting stations for producing harmonics of the line carrier wave, means at each of the radio transmitting stations for increasing the frequency of said wave to the same degree to produce at each station a radio carrier wave of comparatively high frequency relatively to that of the line carrier wave by filtering out a desired harmonic of the line carrier wave, means at the master control station for generating a wave varying in accordance with signals, means comprising line wires for transmitting signal variations to each radio transmitting station, and means at each radio transmitting station for modulating the radio carrier wave by the signal variations.

21. In a communication network including a number of radio receiving stations, means to transmit by radio to said stations side band components of signal modulated waves without the unmodulated carrier component, means to supply continuous waves to said stations by wire from a common point, and means at said radio receiving stations for combining with the side band components received by radio, waves derived from said continuous waves to receive the signal.

22. The method of secret signaling which comprises controlling the action of signal transmitting apparatus so as to produce two complementary components of a signal modulated wave, both of which are essential to intelligible reception of the signal, broadcasting one component and separately supplying the other component by point-to-point transmission to those receiving stations, in the field of said broadcast component, with which it is desired to communicate.

23. The method of wide area broadcasting which comprises generating variations corresponding to the signals to be broadcast, conveying said signal variations by wire to a plurality of broadcasting radio transmitting stations, impressing said signal variations upon radio frequency currents produced at each of said stations, and radiating simultaneously from each said station, electromagnetic waves having a common single carrier frequency and modulated in common by said signal variations.

24. A radio transmission system comprising a master control station and a plurality of radio transmitting stations, means at the control station for generating a line wire

carrier wave, means comprising line wires for transmitting the carrier wave to each radio transmitting station, means at each of the radio transmitting stations to produce at
 5 each station a radio carrier wave synchronized by the line carrier wave, means at the master control station for generating a wave which varies in accordance with a wave of signal frequency, means comprising line
 10 wires for transmitting the signal frequency wave to each radio transmitting station, and means at each radio transmitting station for modulating the radio carrier wave by the signal frequency wave.

15 25. In combination, a plurality of radio transmitting stations spaced at distances that are independent of the wave length of transmission therefrom, an antenna system at each of said stations, said antenna system
 20 being capable of radiating electromagnetic waves with substantially equal effectiveness in many horizontal directions, means for fixing the radiation frequency of all of the stations at the same value at any instant, said
 25 means comprising a frequency control station and a control frequency channel linking said frequency control station directly with a plurality of said radio transmitting stations, means for generating a control fre-
 30 quency associated with said control frequency channel, means at each transmitting station for deriving a radiation frequency from said control frequency, and a modulation control system comprising a signal gen-
 35 erating apparatus and means for linking the same with each of said radio transmitting stations whereby the waves transmitted therefrom are simultaneously modulated by the same signal.

40 26. A radio transmission system adapted to supply broadcast programs to a plurality of radio receivers and comprising a master control station and a group of radio transmitting stations, a control frequency
 45 channel comprising line wires linking the control station and the transmitting stations, said transmitting stations being spaced from each other by such distances that each individual member of the group
 50 may constitute a separate distributing center for radio broadcasting whereby a given receiver may be within the signal audibility range of one only or of a plurality of said group, means at the control station for gen-
 55 erating a carrier wave for transmission over the control channel and having the comparatively low frequency of line wire carrier waves, means at the control station for generating a signal wave and means for modu-
 60 lating at the control station said carrier wave by the signal wave, means at each of the transmitting stations for increasing by the same amount the frequency of the modulated carrier wave to a comparatively high
 65 radio carrier frequency, and means at each

transmitting station for radiating a modulated carrier wave of increased frequency.

In witness whereof, I hereunto subscribe my name this 30th day of January A. D., 1924.

JAMES W. SCHMIED.

70

75

80

85

90

95

100

105

110

115

120

125

130