

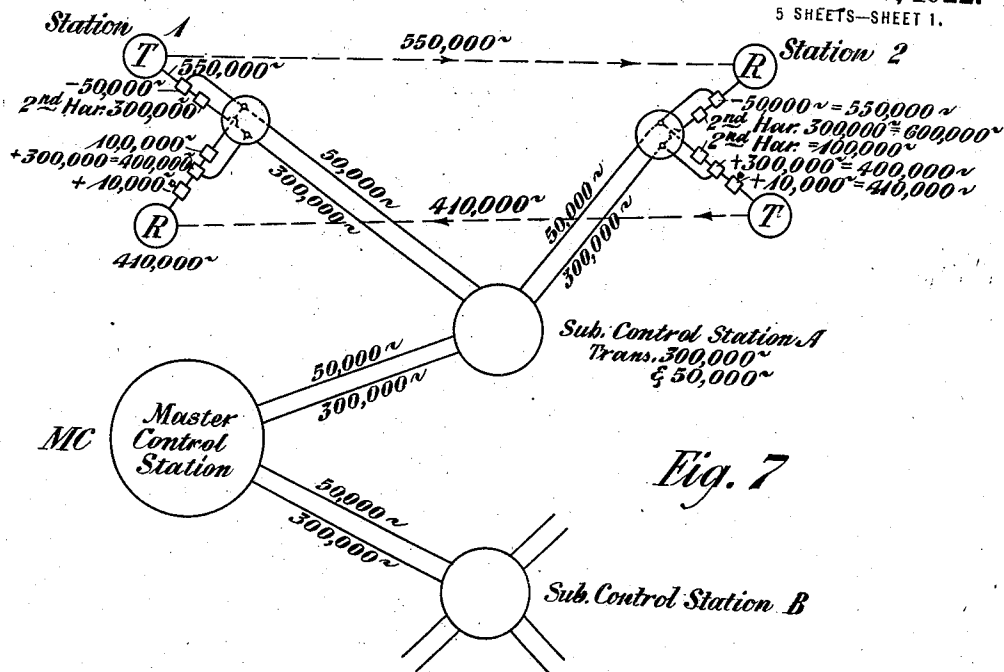


Fig. 7

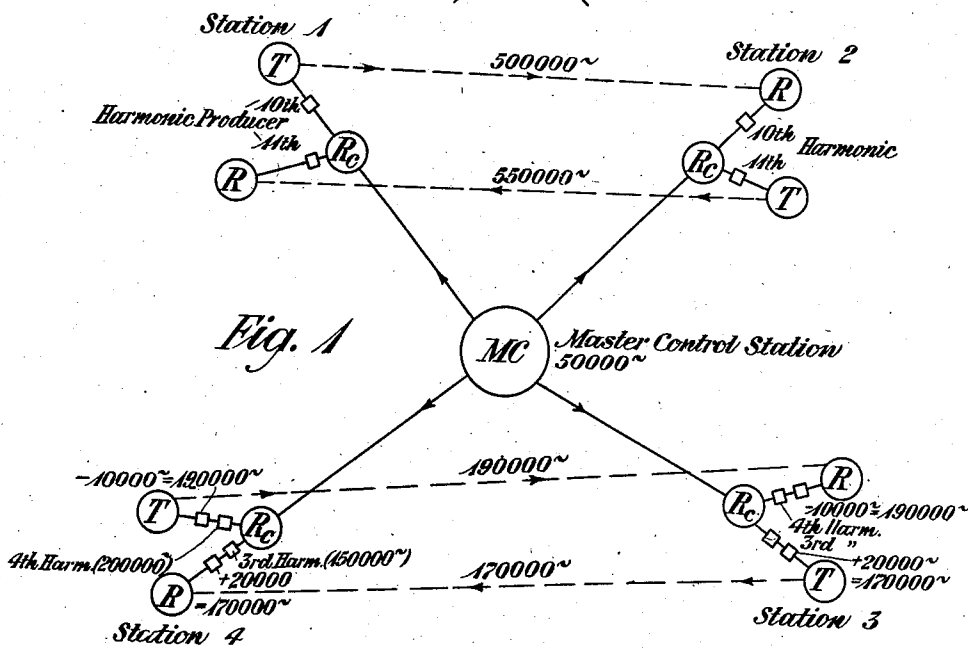


Fig. 1

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O. B. BLACKWELL.
FREQUENCY CONTROL SYSTEM.

APPLICATION FILED SEPT. 30, 1919. RENEWED APR. 19, 1920.

1,403,835.

Patented Jan. 17, 1922.

5 SHEETS—SHEET 2.

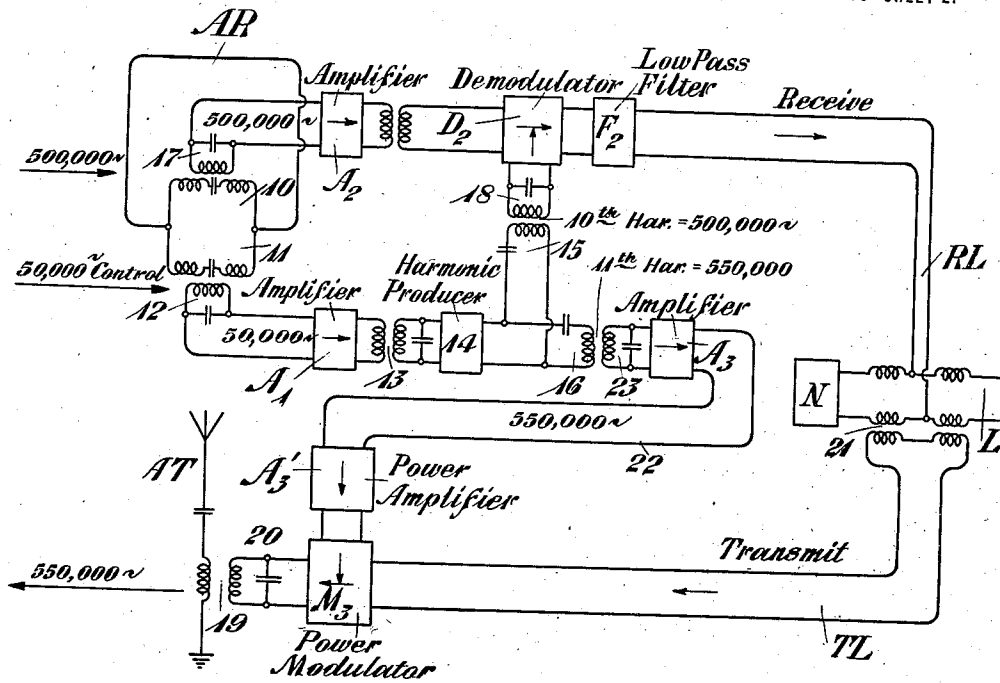


Fig. 2

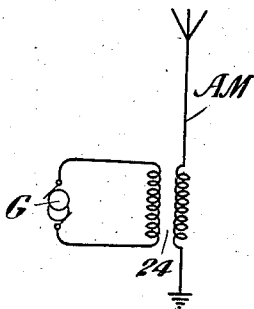


Fig. 3

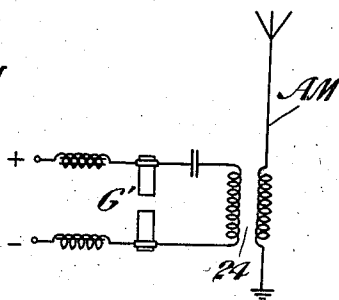


Fig. 4

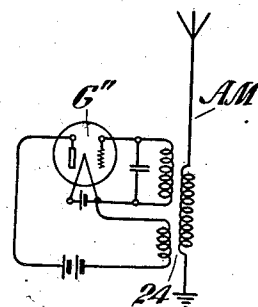


Fig. 5

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5 SHEETS—SHEET 3.

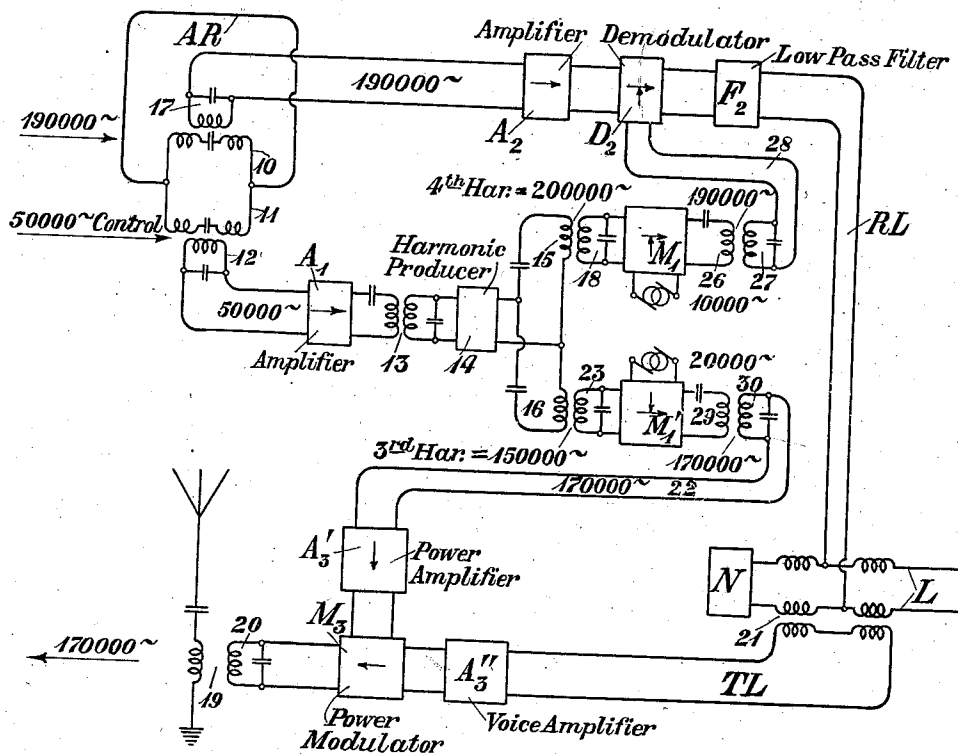


Fig. 6

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5 SHEETS—SHEET 4.

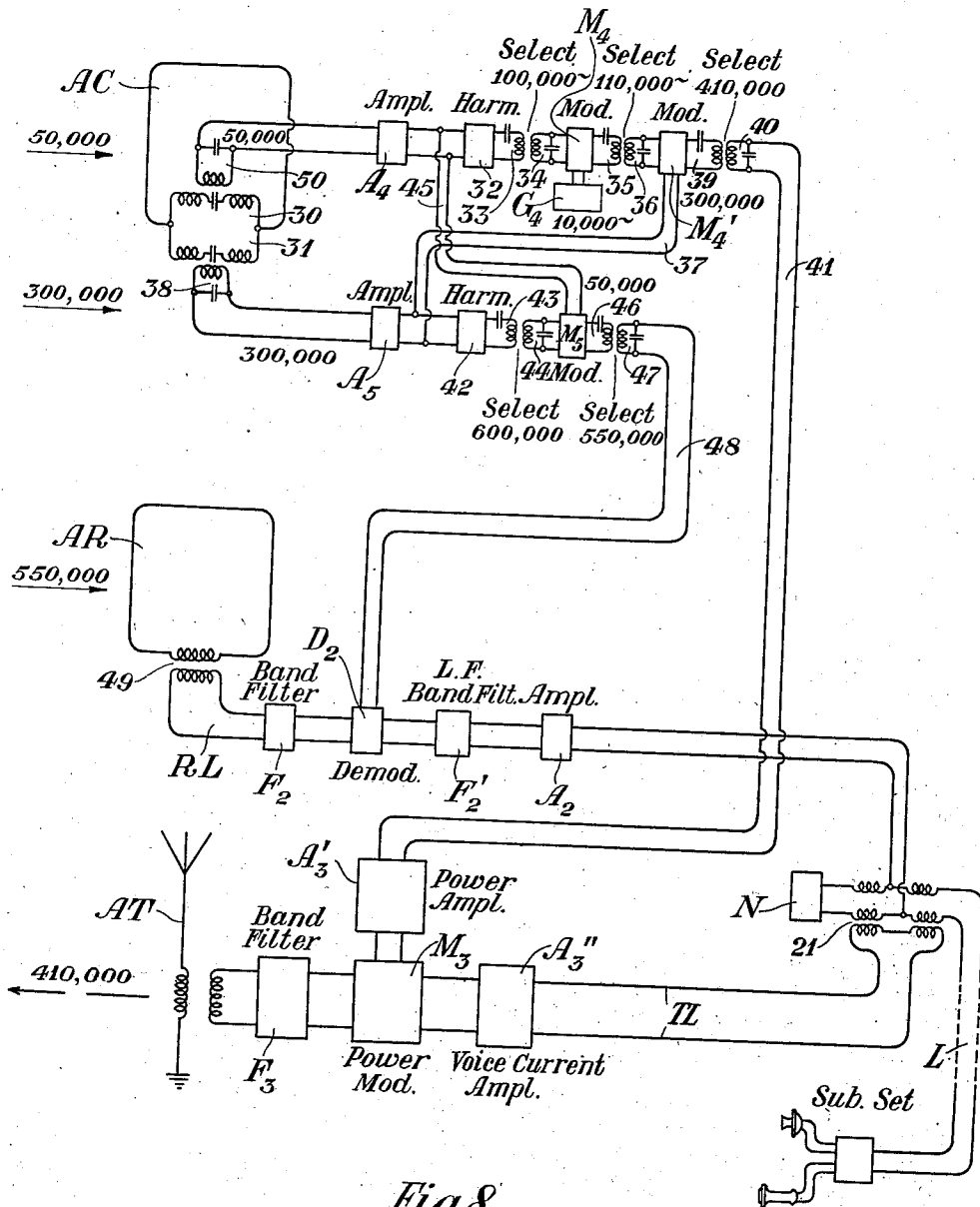
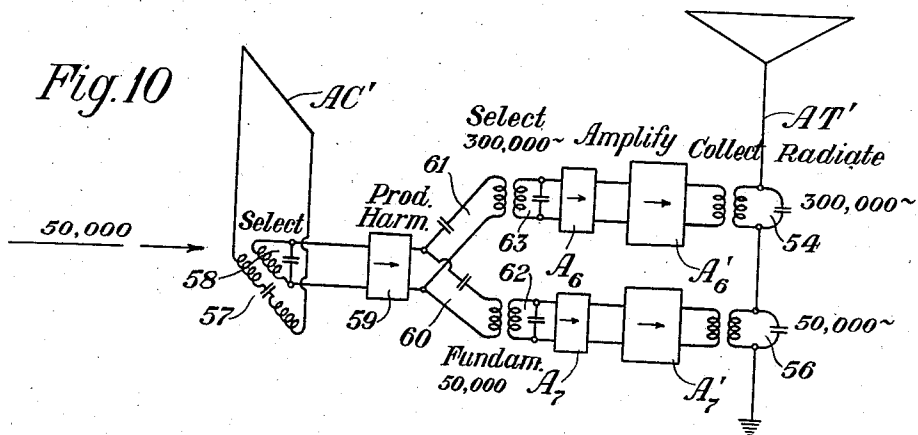
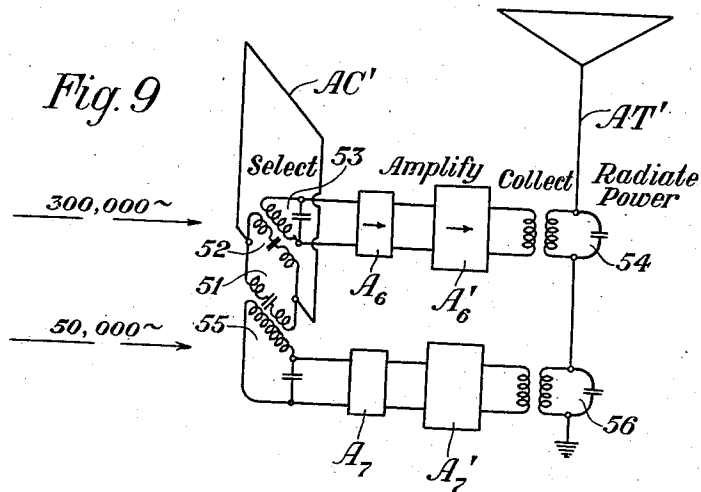


Fig. 8

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UNITED STATES PATENT OFFICE.

OTTO B. BLACKWELL, OF GARDEN CITY, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

FREQUENCY-CONTROL SYSTEM

1,403,835.

Specification of Letters Patent. Patented Jan. 17, 1922.

Application filed September 30, 1919, Serial No. 327,405. Renewed April 19, 1920. Serial No. 375,149.

To all whom it may concern:

Be it known that I, OTTO B. BLACKWELL, residing at Garden City, in the county of Nassau and State of New York, have invented certain Improvements in Frequency-Control Systems, of which the following is a specification.

This invention relates to radio signaling and more particularly to arrangements for controlling the signaling frequency used by different stations.

In radio signaling where a large number of signaling stations are to signal simultaneously, it is desirable that each pair of communicating stations signal at one or more radio frequencies differing from the frequencies used by all other pairs of communicating stations, in order to avoid interference. Furthermore, the various signaling stations may be divided up into groups or systems depending upon the corporation or other interest controlling the system or group. Since but one frequency spectrum is available to all of the parties interested, it is desirable that the spectrum be divided up and certain ranges of frequencies be assigned to each group. The organization operating a given group of stations will then have available for signaling as many channels as can be included within the range assigned and these channels may be individual channels for individual signaling stations or a plurality of channels may be assigned to a station for multiplex signaling.

In order to prevent the stations of one group from overlapping in their operation the range of frequencies assigned to another group, it is desirable that some means or method be provided for definitely relating the frequencies of the various groups with reference to each other, so that a shifting of the band of frequencies utilized by one group will cause a corresponding shifting of the frequencies utilized by other groups. In accordance with the present invention this result may be secured by generating at a master station one or more fundamental frequencies which may be radiated to the stations of the various groups or systems, the various signaling frequencies to be used by individual stations of the groups being derived from the received fundamental frequency or frequencies.

More specifically considered, the method comprises generating at the master station one or more fundamental radio frequencies which may be radiated to all of the stations of the various groups or systems. If necessary, the fundamental frequency or frequencies may be amplified at intermediate points, where the distances involved are very great. At each signaling station the radiated controlling frequency or frequencies will be received. Where but one controlling frequency is radiated this frequency should be as low as possible, consistent with efficient radiation and radio frequencies for different stations or groups of stations may be obtained as harmonics of the fundamental frequency. It will, of course, be desirable to produce other radio frequencies on either side of the harmonic frequency and these additional frequencies may be produced by locally generating a low frequency and combining either this low frequency, or some harmonic thereof; with the radio frequency produced directly from the fundamental. Where a plurality of fundamental frequencies are transmitted, a greater range of individual radio frequencies for different groups or stations of groups may be produced by combining the fundamental frequencies or harmonics thereof in such a manner as to add and subtract frequencies in accordance with the well understood principles of modulation. Closely related radio frequencies in the neighborhood of the frequencies thus produced may be obtained, as before, by locally generating a low frequency, which low frequency, or one of its harmonics, may be combined with the radio frequency to produce another radio frequency above or below it.

By a proper choice of fundamental frequencies it will even be possible to absolutely fix this low frequency for all stations, instead of generating it at each station, since two closely spaced fundamental frequencies may be transmitted whose difference is equal to the desired low frequency, or three widely separated fundamentals may be so chosen that the difference between two differs from a third by a relatively small frequency difference equal to the desired low frequency, or so that the difference between one pair differs from the difference

between another pair by the desired low frequency.

The invention may now be more fully understood from the following description when read in connection with the accompanying drawing in which,

Figure 1 is a schematic diagram illustrating broadly one method of carrying out the invention.

Figure 2 is a diagram of one of the signaling stations schematically indicated in Figure 1.

Figures 3, 4 and 5 are diagrams of a number of modifications of the apparatus at the master controlling station.

Figure 6 is a diagram of another signaling station schematically indicated in Figure 1.

Figure 7 is a schematic diagram illustrating another method of practicing the invention.

Figure 8 is a circuit diagram of the apparatus of one of the signaling stations at Figure 7, and

Figures 9 and 10 are diagrams of sub-control or repeating stations adapted to relay fundamental frequencies from the master station.

Referring to Figure 1, MC designates a master control station at which apparatus hereinafter described may be provided to radiate a fundamental radio frequency of say 50,000 cycles, which is to be picked up by the various other stations and translated into the particular radio frequency used for intercommunication between any pair of stations. Two pairs of intercommunicating stations 1—2 and 3—4 are schematically illustrated in Figure 1, each pair being typical of a larger group, and it being further understood that in actual practice more than two stations may intercommunicate at the same frequency. Each station may include an apparatus schematically indicated as R_c, for receiving the master controlling frequency, together with suitable apparatus for translating the frequency into the frequency or frequencies used for intercommunication and for supplying said frequency or frequencies to a transmitter and receiver conventionally illustrated and designated in the drawing as T and R, respectively.

Suppose it is desired to transmit from station 1 to station 2 at a radio carrier frequency of 500,000 cycles and to transmit from station 2 to station 1 at a radio carrier frequency of 550,000 cycles. In order to derive these frequencies the received control frequency of 50,000 cycles may be impressed upon a harmonic producer. The tenth harmonic of 50,000 cycles is 500,000 cycles and this may be supplied to the transmitting apparatus T at station 1. The eleventh harmonic of 50,000 cycles is 550,000 cycles and this frequency may be

supplied to the receiving apparatus R at station 1. The same frequencies may be produced at station 2 in the same manner, except that in this case the frequencies supplied to the transmitting and receiving apparatus, respectively, will be interchanged.

Where it is desired to signal by means of carrier frequencies which are not direct harmonics of the fundamental, the problem is slightly more involved. This situation is illustrated in connection with stations 3 and 4, which are supposed to intercommunicate upon frequencies of 190,000 and 170,000 cycles, respectively. At station 3 the apparatus R_c will receive the fundamental of 50,000 cycles and the fourth harmonic of this frequency, which is 200,000 cycles, may be produced by means of a harmonic producer, in the manner already described. By modulating this harmonic with a locally generated frequency of 10,000 cycles, frequencies of 210,000 and 190,000 cycles, respectively, will be produced, in accordance with the well understood principles of modulation, and the former of these may be suppressed by means of a filtering arrangement, so that 190,000 cycles may be supplied to the receiving apparatus R. One hundred and seventy thousand cycles may be supplied to the transmitting apparatus T, by producing the third harmonic of 50,000, which is 150,000 cycles and modulating this harmonic with a locally generated frequency of 20,000 cycles. The frequency 20,000 may in turn be produced by taking the second harmonic of 10,000 cycles.

Figure 2 illustrates the apparatus associated with the station 2, for example. In this figure AR designates a receiving antenna in the form of a balanced loop, which is so related to a transmitting antenna AT that radiations from AT will be balanced out in the two halves of the loop, with respect to the receiving circuit. The loop AR may be made resonant to two frequencies by means of two parallel branches 10 and 11, the latter of which may be tuned in a well known manner to receive the control frequency of 50,000 cycles and the former of which may be tuned to receive the radio receiving frequency of the station, which is 500,000 cycles. The branch 11 is coupled through a tuned circuit 12 to a circuit including an amplifier A₁, for amplifying the 50,000 cycles control frequency. The amplifier A₁ may be of any well known type, but is preferably a vacuum tube amplifier. The amplifier A₁ is associated through a transformer and tuned circuit arrangement 13 with a harmonic producer 14. The harmonic producer 14 is a well known piece of apparatus and is preferably a distorting tube arrangement such as is disclosed in the U. S. application of B. W. Kendall, Serial No. 139,530, filed December 29, 1916. As a result of the action of this

harmonic producer, various harmonics of 50,000 cycles appear in the output circuit of the apparatus 14. The tenth harmonic, corresponding to 500,000 cycles, may be selected out for receiving purposes by means of a tuned circuit 15, while the eleventh harmonic, corresponding to 550,000 cycles, may be selected out for transmitting purposes, by another branch circuit 16, tuned to this harmonic.

The receiving branch 10, which is resonant at the receiving carrier frequency 500,000 cycles, is coupled to a locally tuned circuit 17 of the same frequency, which is associated with an amplifier A_2 , similar to the amplifier A_1 , for amplifying modulated received frequencies in the neighborhood of 500,000 cycles. The amplified frequencies are then impressed upon a demodulator D_2 , which, in accordance with the homodyne principle of receiving, is supplied with local oscillations of the carrier frequency, through a tuned circuit 18 associated with the tuned circuit 15, thereby supplying homodyne current of 500,000 cycles. The demodulator D_2 may be of any well known type, but is preferably a vacuum tube demodulator. If desired, a low pass filter F_2 may be included in the output circuit of the demodulator, for the purpose of suppressing the high frequency components and freely transmitting the detected low frequency signals which are then supplied over the circuit RL to the signaling line L. The low pass filter F_2 may be a broad band filter of the type disclosed in the U. S. patents to George A. Campbell, Nos. 1,227,113 and 1,227,114, issued May 22, 1917.

The transmitting antenna AT may be tuned to the transmitting frequency of 550,000 cycles and is coupled through a transformer 19 with a locally tuned circuit 20 which is associated with a power modulator M_3 . The modulator M_3 may be of any well known type, such for instance as the well known vacuum tube modulator. The signaling currents are supplied to this modulator over a circuit TL which is associated with the signaling line L, by means of a balanced transformer 21 of a well known type. The circuits RL and TL are rendered conjugate by balancing the line L with an artificial line N, in a well known manner. The carrier frequency of 550,000 cycles is supplied to the power modulator M_3 over a circuit 22, terminating in a resonant circuit 23, coupled with the resonant circuit 16 and tuned to the same harmonic, viz. 550,000 cycles. The circuit 22 includes an amplifier A_3 for amplifying the desired harmonic and may also include a second more powerful amplifier A_3' for further amplifying the carrier frequency.

The apparatus at the master control station is illustrated in Figure 3 and may comprise a master antenna AM, coupled through a transformer 24 with an alternator G adapt-

ed to supply oscillations of 50,000 cycles or of any other frequency which may be determined upon as the fundamental frequency. Instead of an alternator, a Poulsen arc generator G' may be substituted, as illustrated in Figure 3, or a vacuum tube oscillator G'' may be used, as illustrated in Figure 5.

The operation of the arrangement shown in Figure 2 is briefly as follows: Assuming that a fundamental frequency of 50,000 is radiated from a master station such as that illustrated in Figure 3 for example, this frequency will be received by means of the antenna AR and will be transmitted through the tuned circuits 11 and 12 to the amplifier A_1 . The amplified frequency is then impressed upon a harmonic producer 14, thereby producing various harmonics of the fundamental frequency, of which the tenth and eleventh harmonic may be selected by means of the circuits 15 and 16, which are coupled with the tuned circuits 18 and 19, respectively. From the circuit 18 the tenth harmonic may be supplied to the demodulator. The eleventh harmonic appearing in the tuned circuit 23 is amplified by the amplifiers A_3 and A_3' and supplied to the power modulator M_3 .

Low frequency signals incoming from the line L₁ are transmitted through the transformer 21 to the circuit TL and through the modulator M_3 to modulate a carrier frequency of 550,000 cycles and the modulated carrier currents are then radiated from the antenna AT. Owing to the relation of the transmitting antenna AT to the receiving antenna AR, the energy radiated from the transmitting antenna AT to said receiving antenna is substantially without effect, as equal and opposite potentials tend to be produced in the tuned circuits 10 and 11. Received modulated carrier frequencies in the neighborhood of 500,000 cycles are absorbed by the receiving antenna AR and are transmitted from the tuned circuit 10 to the tuned circuit 7 and impressed upon the amplifier A_2 . After being amplified, the received modulated carrier currents are impressed upon the demodulator D_2 and react with the locally supplied frequency of 500,000 cycles from the circuit 18 to detect low frequency signaling currents which are passed through the low pass filter F_2 over the circuit RL to the line 1.

Figure 6 illustrates the apparatus which may be provided at station 3. In this figure, since reception is to take place at 190,000 cycles, the circuits 10 and 17 are tuned to this frequency, instead of 500,000 cycles. The harmonic producer 14, as before, is provided with tuned branches 15 and 16, these branches in this instance being tuned to the fourth and third harmonics, respectively, corresponding to 200,000 cycles and 150,000 cycles. These circuits are coupled to tuned

circuits 18 and 23, tuned to the same frequency, but in this instance circuits 18 and 23, instead of being connected directly to the demodulator D_2 and modulator M_3 , respectively, are associated with modulators M_1 and M_1' respectively. The modulator M_1 is supplied with a locally generated frequency of 10,000 cycles, in accordance with which the fourth harmonic of 200,000 cycles may be modulated, thereby producing frequencies equal to the sum and difference of the two frequencies. The former frequency (210,000 cycles) may be suppressed and the latter frequency (190,000 cycles) may be transmitted by means of tuned circuits 26 and 27 to a circuit 28, leading to the demodulator D_2 . The modulator M_1' is supplied with a locally generated frequency of 20,000 cycles, which modulates the third harmonic of 150,000 cycles, thereby producing again sum and difference frequencies. In this instance the latter frequency corresponding to 130,000 cycles is suppressed and the former (170,000 cycles) is transmitted through tuned circuits 29 and 30 to the circuit 22 leading through the amplifier A_3' to the modulator M_3 .

The operation is as follows: The controlling frequency of 50,000 cycles is received by the antenna AR, as before, and passes through the tuned circuits 11 and 12 to the amplifier A_1 . This frequency is then amplified and impressed upon the harmonic producer 14 and the third and fourth harmonics are selected by means of the circuit 16 and 15, respectively. The fourth harmonic, corresponding to 200,000 cycles, is combined with a locally generated frequency of 10,000 cycles in the modulator M_1 and the difference in the two frequencies is selected by means of tuned circuits 26 and 27, so that a frequency of 190,000 cycles is supplied to the demodulator D_2 . The third harmonic of 150,000 cycles is combined in the modulator M_1' with a locally generated frequency of 20,000 cycles and the resultant frequency of 170,000 cycles is selected by means of tuned circuits 29 and 30 and transmitted over the circuit 22 to the power amplifier A_3' , for supplying the modulator M_3 . The operation of transmission and reception will be similar to that described in connection with Figure 2 and need not be further considered.

Figure 7 illustrates a slight variation of the method illustrated in Figure 1. In this case a master controlling station MC radiates two frequencies which may be, for example, 50,000 and 300,000 cycles. Where the distance to the signaling stations, such as 1 and 2, is too great for direct radiation, intermediate repeating or sub-controlling stations such as A and B may be provided for amplifying the fundamental frequencies and re-transmitting them with sufficient power

to be readily received at the signaling stations, such as 1 and 2. The fundamental frequencies may be combined to produce any desired carrier frequency at a given signaling station. For instance, in connection with stations 1 and 2 carrier frequencies of 550,000 cycles and 410,000 cycles may be produced.

The manner in which this may be done will be more fully understood from the apparatus disclosed in Figure 8, said diagram illustrating the arrangements of station 2. In Figure 8 a special loop receiving antenna AC is provided for receiving fundamental frequencies, another loop antenna AR being provided for receiving signaling frequencies. Both of these loop antennae are balanced with respect to the transmitting antenna AT. The loop AC is provided with tuned branches 30 and 31, the former being tuned to the control frequency of 50,000 cycles and the latter to the control frequency of 300,000 cycles. The branch 30 is coupled to a tuned circuit 31 which is associated with an amplifier A_1 for amplifying the control frequency. The output circuit of the amplifier A_1 is associated with a harmonic producer 32 of the type already described. A tuned circuit 33 in the output of the harmonic producer is adapted to select the second harmonic corresponding to a frequency of 100,000 cycles. A tuned circuit 33 is coupled to a similarly tuned circuit 34 associated with the input of a modulator M_1 which is also supplied with a locally generated frequency of 10,000 cycles from a generator G_1 . The modulator acts to produce in its output circuit frequencies corresponding to the sum and difference of the two frequencies applied to the input and the former of these frequencies, which corresponds to 110,000 cycles, is selected by a tuned circuit 35 and impressed upon a second tuned circuit 36 associated with the input of a modulator M_1' . The modulator M_1' is also supplied with a frequency of 300,000 cycles from a circuit 37 in a manner hereinafter described.

The tuned branch 31 of the antenna AC is coupled to a tuned circuit 38, which is also resonant to 300,000 cycles. This tuned circuit is associated with an amplifier A_2 for amplifying this controlling frequency. The output circuit of the amplifier is connected to the circuit 37, to supply a frequency of 300,000 cycles to the modulator M_1' . As a result of the action of the modulator M_1' , the sum and differences appear in the output circuit of the modulator and the former, corresponding to a frequency of 410,000 cycles, is selected by the tuned circuit 39 and impressed upon the tuned circuit 40 associated with the supply circuit 41, which supplies the carrier frequency of 410,000 cycles for the transmitting apparatus.

The output circuit of the amplifier A_5 is also connected to a harmonic producer 42 which may be of the same character as the harmonic producer 32. The second harmonic is selected from the harmonic producer by the tuned circuit 43 which is coupled with a similar tuned circuit 44, so that a frequency of 600,000 cycles is impressed upon the modulator M_5 . The modulator M_5 is also supplied with the controlling frequency of 50,000 cycles over a circuit 45, which is connected to the output of the amplifier A_4 . As the result of the interaction of the frequencies 600,000 and 50,000 cycles in the modulator M_5 , the sum and difference frequencies appear in the output circuit of the modulator and the latter, corresponding to a frequency of 550,000 cycles, is selected by the tuned circuit 46 and impressed through the tuned circuit 47 upon the supply circuit 48, which supplies the carrier frequency of 550,000 cycles to the receiving apparatus.

The receiving apparatus comprises the antenna AR, hereinbefore referred to, which is coupled through a transformer 49 to a receiving channel RL, including a band filter F_2 , designed to transmit a band of frequencies in the neighborhood of the carrier frequency used during reception, a demodulator D_2 , a low pass band filter F_2' adapted to suppress carrier frequencies and transmit only low frequency signaling currents, and an amplifier A_2 for amplifying the low frequency detected currents.

The transmitting apparatus includes the antenna AT hereinbefore referred to, a band filter F_3 adapted to transmit a band of frequencies in the neighborhood of 410,000 cycles, a power modulator M_3 and a voice current amplifier A_3'' . The power modulator M_3 is supplied with carrier currents of the proper frequency over the circuit 41, which includes a power amplifier A_3' for amplifying the carrier currents.

The circuits RL and TL are associated with the low frequency line L through a balanced transformer arrangement 21. These circuits are rendered conjugate by balancing the line L with an artificial line or network N, in a well known manner.

The operation is as follows: The controlling frequencies of 50,000 and 300,000 cycles, respectively, are received by the loop antenna AC and are transmitted through tuned circuits 30—50 and 31—38 to the amplifiers A_4 and A_5 , respectively. The frequency of 50,000 cycles is amplified by the amplifier A_4 and then impressed upon the harmonic producer 32, so that harmonics of this frequency are produced. The tuned circuit 33 picks out the second harmonic corresponding to 100,000 cycles and this frequency is transmitted through the tuned circuit 34 to the modulator M_4 . The modulator M_4 is also supplied with a locally generated frequency of 10,000 cycles, so that a frequency of 110,000 cycles appears in its output circuit, which is selected by the tuned circuit 35 and impressed by the tuned circuit 36 upon the modulator M_4' . This modulator is also supplied over the circuit 37, from the amplifier A_5 with the controlling frequency of 300,000 cycles, so that this frequency is combined with 110,000 cycles to produce in the output circuit of the modulator M_4' a frequency of 410,000 cycles. This frequency is selected by the tuned circuit 39 and impressed through the tuned circuit 40 upon the supply circuit 41, which leads through the amplifier A_3' to the power modulator M_3 of the transmitting apparatus.

The 300,000 cycle control frequency amplified by the amplifier A_5 is impressed upon the harmonic producer 42, as a result of which various harmonics of this frequency appear in its output circuit. The second harmonic, corresponding to a frequency of 600,000 cycles is selected by the tuned circuit 43 and passed through the tuned circuit 44 to the modulator M_5 . The modulator M_5 is also supplied with the controlling frequency of 50,000 cycles over the circuit 45 which is connected to the output side of the amplifier A_4 . The frequency of 600,000 cycles and 50,000 cycles are combined in the modulator M_5 to produce a frequency of 550,000 cycles, which is selected by the tuned circuit 46 and impressed through the tuned circuit 47 upon the supply circuit 48 leading to the demodulator D_2 of the receiving apparatus.

The operation of transmitting and receiving by means of the apparatus associated with the antennae AT and AR will be similar to that already described in connection with previous modifications and need not be further considered.

The amplifying apparatus provided at sub-control stations, such as the station A of Figure 7, may be of the type illustrated in Figure 9. In this figure AC' designates a receiving antenna having tuned branches 51 and 52, which may be resonant to 50,000 cycles and 300,000 cycles, respectively. The frequency of 300,000 cycles is transmitted from the tuned circuit 52 to a resonant circuit 53, tuned to the same frequency and associated with the input circuit of amplifiers A_6 and A_7 . These amplifiers may be of any well known character, such, for instance, as vacuum tube amplifiers. The output circuit of the amplifier A_7 is coupled to a resonant circuit 54 in the transmitting antenna AT'. The latter is associated with the receiving antenna AC' in such a manner that the energy radiated by the transmitting antenna will produce substantially no effect upon the receiving and amplifying apparatus associated with the receiving antenna.

The tuned circuit 51 is coupled to a tuned circuit 55, also resonant at 50,000 cycles, said tuned circuit being associated with the input circuits of amplifiers A_7 and A_7' , which may be similar to the amplifying apparatus A_6 and A_6' , already referred to. The output circuit of the amplifier A_7' is coupled to a tuned circuit 56 in the transmitting antenna AT' .

- 10 The operation is as follows: Controlling frequencies of 300,000 and 50,000 cycles, respectively, are received by the antenna AC' and impressed upon the amplifying arrangements A_6-A_6' , A_7-A_7' , respectively, and after being amplified are radiated by the antenna AT' . As already stated, the antenna AT' is in a direction normal to the plane of the loop AC' , so that equal and opposite effects are produced in the tuned circuits 51 and 52, thereby preventing singing of the repeater circuit.

- Figure 10 illustrates an amplifying arrangement adapted to be used where a single control frequency is radiated from the master station and two controlling frequencies are then generated at the repeating station from this fundamental frequency to be radiated to the various signaling stations. In this case the receiving antenna AC' is provided with a single branch 57, which may be tuned to 50,000 cycles, for instance, this branch being coupled to a tuned circuit 58 resonant at the same frequency. The tuned circuit 58 is connected to a harmonic producer 59, similar to those already described, which produces harmonics of 50,000 cycles. Tuned branches 60 and 61 in the output circuit of the harmonic producer 59 select the fundamental frequency of 50,000 cycles and the sixth harmonic thereof, which corresponds to a frequency of 300,000 cycles. These two frequencies are impressed upon the tuned circuits 62 and 63 and are amplified by the amplifiers A_6-A_6' and A_7-A_7' , respectively. The amplified frequencies are then impressed upon the tuned circuits 54 and 56 in the transmitting antenna AT' and are radiated to the signaling station.

- It will be understood that the frequencies hereinbefore referred to are given for purposes of illustration only and that these frequencies may be varied as practical conditions required. Furthermore, although the frequency control channels are illustrated as being transmitted by radio they may be transmitted in any other manner desired as by a wire circuit. It will also be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated, without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. In a radio system in which a plurality of radio stations are divided into groups of

intercommunicating stations, each group having assigned to it a definite frequency range which shall not interfere with the frequency range assigned to any other group, the method of controlling the frequencies used for signaling in the various groups, which consists in generating at a master station a fundamental frequency, transmitting said frequency to the stations of the various groups and translating at said stations the fundamental frequency into frequencies within the range assigned to the group.

2. In a radio system in which a plurality of radio stations are divided into groups of intercommunicating stations, each group having assigned to it a definite frequency range which shall not interfere with the frequency range assigned to any other group, the method of controlling the frequencies used for signaling in the various groups, which consists in generating at a master station a plurality of frequencies, transmitting said frequencies to the stations of the various groups and translating at the stations of each group said fundamental frequencies into frequencies within the range assigned to the group.

3. In a radio system in which a plurality of radio stations are divided into groups of intercommunicating stations, each group having assigned to it a definite frequency range which shall not interfere with the frequency range assigned to any other group, the method of controlling the frequencies used for signaling in the various groups, which consists in generating at a master station a plurality of fundamental frequencies, radiating said frequencies to the stations in the various groups and producing at certain of the stations of the groups frequencies within the range assigned to the group, by combining said fundamental frequencies.

4. In a radio system in which a plurality of radio stations are divided into groups of intercommunicating stations, each group having assigned to it a definite frequency range which shall not interfere with the frequency range assigned to any other group, the method of controlling the frequencies used for signaling in the various groups, which consists in generating at a master station a plurality of fundamental frequencies, radiating said frequencies to the stations in the various groups, and producing at certain of the stations of a group frequencies within the range assigned to the group, by the producing harmonics of at least one of said frequencies and combining said harmonics with another frequency.

5. In a radio system in which a plurality of radio stations are divided into groups of intercommunicating stations, each group having assigned to it a definite frequency range which shall not interfere with the fre-

quency range assigned to any other group, the method of controlling the frequencies used for signaling in the various groups, which consists in generating at a master station a plurality of fundamental frequencies, transmitting said frequencies to stations in each group, and producing at the stations of the groups frequencies within the range assigned to the group, by combining said fundamental frequencies and harmonics of said frequencies.

6. In a radio system in which a plurality of radio stations are divided into groups of intercommunicating stations, each group having assigned to it a definite frequency range which shall not interfere with the frequency range assigned to any other group, the method of controlling the frequencies used for signaling in the various groups, which consists in generating at a master station a plurality of fundamental frequencies, radiating said fundamental frequencies to the stations in the various groups, and producing at the stations of the various groups frequencies within the range assigned to the group, by combining frequencies produced at said stations and determined by said fundamental frequencies, with other frequencies.

7. In a radio system in which a plurality of radio stations are divided in groups of intercommunicating stations, each group having assigned to it a definite frequency range which shall not interfere with the frequency range assigned to any other group, the method of controlling the frequencies used for signaling in the various groups, which consists in generating at a master station a fundamental frequency, radiating said frequency to the stations of the various groups and producing at the stations of the groups frequencies within the range assigned to a group, by combining with another frequency frequencies produced at said stations and depending upon said fundamental frequencies.

8. In a radio system in which a plurality of radio stations are divided into groups of intercommunicating stations, each group having assigned to it a definite frequency range which shall not interfere with the frequency range assigned to any other group, the method of controlling the frequencies used for signaling in the various groups, which consists in producing at a master station the fundamental frequency, radiating said fundamental frequency to other stations, amplifying at said other stations the radiated frequency and radiating the amplified frequency to stations of the various groups and translating the fundamental frequency received at the stations of each group into frequencies within the range assigned to the group.

9. In a radio system in which a plurality

of radio stations are divided into groups of intercommunicating stations, each group having assigned to it a definite frequency range which shall not interfere with the frequency range assigned to any other group, the method of controlling the frequencies used for signaling in the various groups, which consists in generating at a master station a plurality of fundamental frequencies, radiating said fundamental frequencies to other stations, amplifying said frequencies at said other stations, radiating the amplified frequencies to the stations of the various groups and translating the fundamental frequencies received at the stations of the various groups into frequencies within the range assigned to the group.

10. The method of preventing relative frequency changes between a plurality of separate radio channels of communication involving a plurality of radio stations, which consists in transmitting a control frequency to each of the radio stations involved, and in deriving from said control frequency at each of said stations the carrier frequencies employed in transmission.

11. The method of fixing the frequency relation between a plurality of non-intercommunicating radio stations, which consists in transmitting to each of said stations a control frequency, and in translating said control frequency into frequencies employed for radio transmission.

12. The method of fixing the frequency relation between a plurality of non-intercommunicating radio stations, which consists in transmitting to each of said stations a control frequency, and translating at said stations said control frequencies into frequencies employed for radio transmission.

13. The method of preventing interference between non-intercommunicating radio stations, which consists in generating at a master station a control frequency, transmitting said frequency to the radio stations involved, and translating at said stations the control frequency into the frequencies of transmission.

14. The method of fixing the frequency relation between a plurality of radio systems, which consists in generating a master control frequency, transmitting said frequency to the terminals of the various radio systems and translating at said terminals said control frequency into frequencies of transmission to be employed in connection with the communicating channels of said radio systems.

15. The method of fixing the frequency relation between a plurality of radio systems, which consists in generating a plurality of master control frequencies, transmitting said frequencies to the terminals of the various radio systems and deriving at said terminals from said control frequencies the

various transmission frequencies to be employed in connection with the communication channels of said radio systems.

16. In a wave length control system, a source of non-signaling control frequency, a plurality of radio stations, some of which are non-intercommunicating, means for transmitting said control frequency to each of said stations, and means at said radio stations for translating said control frequency into frequencies for signal transmission.

17. In a wave length control system, means for producing a plurality of non-signaling control frequencies, a plurality of radio stations, some of which are non-intercommunicating, means for transmitting said control frequencies to said stations, and means at said radio stations for deriving from said control frequencies the frequencies employed for signal transmission.

18. In a radio control system, a master station and a plurality of radio stations, some of which are non-intercommunicating, means to produce at said master station a plurality of control waves, means to transmit said waves to said radio stations, and means at said stations for variously combining the currents of said waves and the harmonic multiples thereof to produce the transmission wave lengths of the various stations.

19. A radio system comprising a plurality of radio stations, means to radiate from one of said stations a non-signaling frequency which is transmitted to each of the other stations, and means at each of the other stations for translating the radiated frequency into different frequencies for signal transmission.

20. In a radio system, a plurality of radio stations, means for radiating from one of said stations to each of the other stations a non-signaling radio frequency, and means at each of said stations for translating said frequency into a higher frequency for signal transmission.

21. In a radio wave length control system, a master station and a plurality of radio stations, some of which are non-intercommunicating, means to radiate from said master station a non-signaling control frequency and means at each of said radio stations for translating said control frequency into a higher frequency for signal transmission.

22. In a radio system in which a plurality of radio stations are divided into groups of intercommunicating stations, each

group having assigned to it a definite frequency range which shall not interfere with the frequency range assigned to any other group, the method of controlling the frequencies used for signaling in the various groups, which consists in generating at a master station a fundamental frequency, transmitting said frequency to the stations of the various groups, and controlling at said stations by means of said fundamental frequencies the frequency of signaling energy produced for signaling within the frequency range assigned to the group.

23. In a radio system in which a plurality of radio stations are divided into groups of intercommunicating stations, each group having assigned to it a definite frequency range which shall not interfere with the frequency range assigned to any other group, the method of controlling the frequencies used for signaling in the various groups, which consists in generating at a master station a plurality of frequencies, transmitting said frequencies to the stations of the various groups, and controlling by means of said frequencies at the stations of each group the frequency of signaling energy produced for signaling within the frequency range assigned to the group.

24. The method of preventing relative frequency changes between a plurality of separate radio channels of communication involving a plurality of radio stations, which consists in transmitting a control frequency to each of the radio stations involved and in controlling by said frequency at each of said stations the frequency of energy produced for carrier frequencies employed in transmission.

25. The method of fixing the frequency relation between a plurality of non-intercommunicating radio stations, which consists in transmitting to each of said stations a control frequency, and in determining by means of said frequency the frequencies of the energy employed for radio transmission.

26. The method of fixing the frequency relation between a plurality of non-intercommunicating radio stations, which consists in transmitting to each of said stations a control frequency, and in determining by said control frequency at said stations the frequencies of the energy employed for radio transmission.

In testimony whereof, I have signed my name to this specification this 29th day of September, 1919.

OTTO B. BLACKWELL.