Nov. 23, 1926. 1,607,682

DE LOSS K. MARTIN

RADIO REPEATER SYSTEM

Filed March 22, 1924

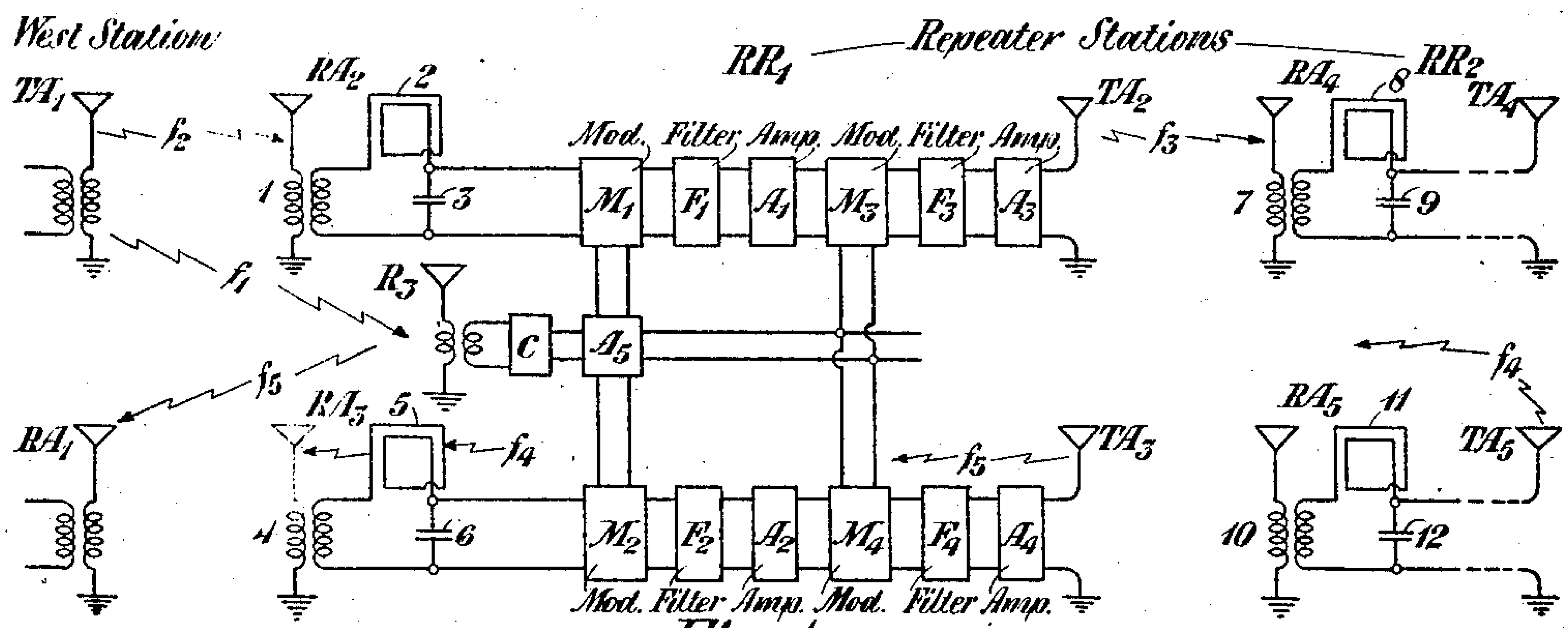

Fig. 1

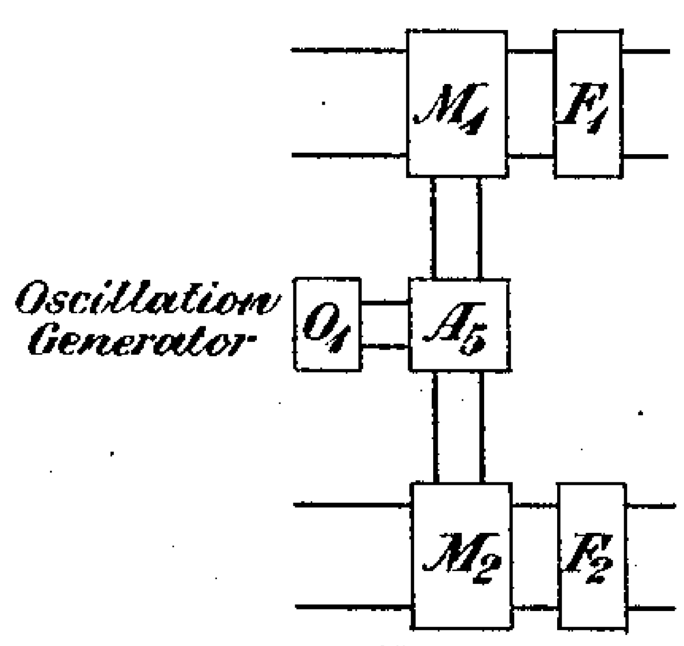

Fig. 1a

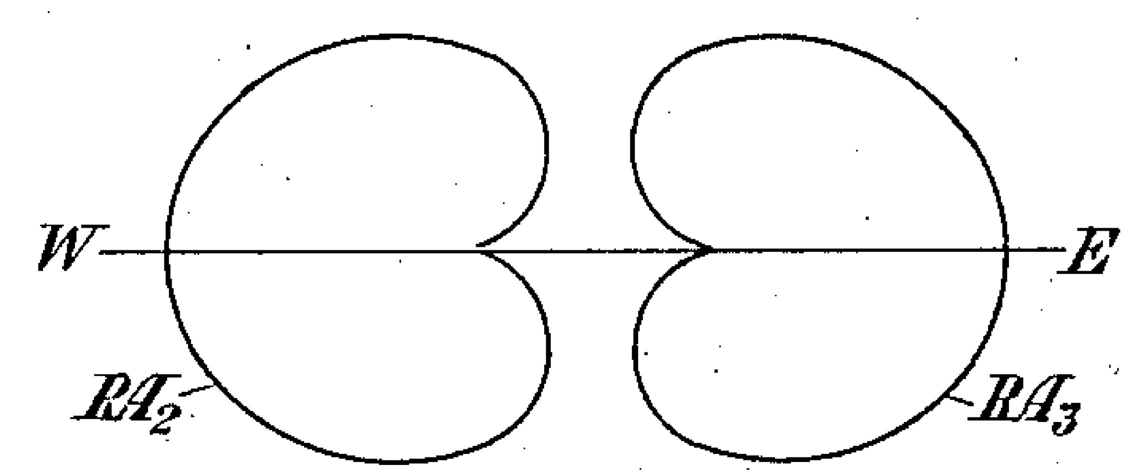

Fig. 2

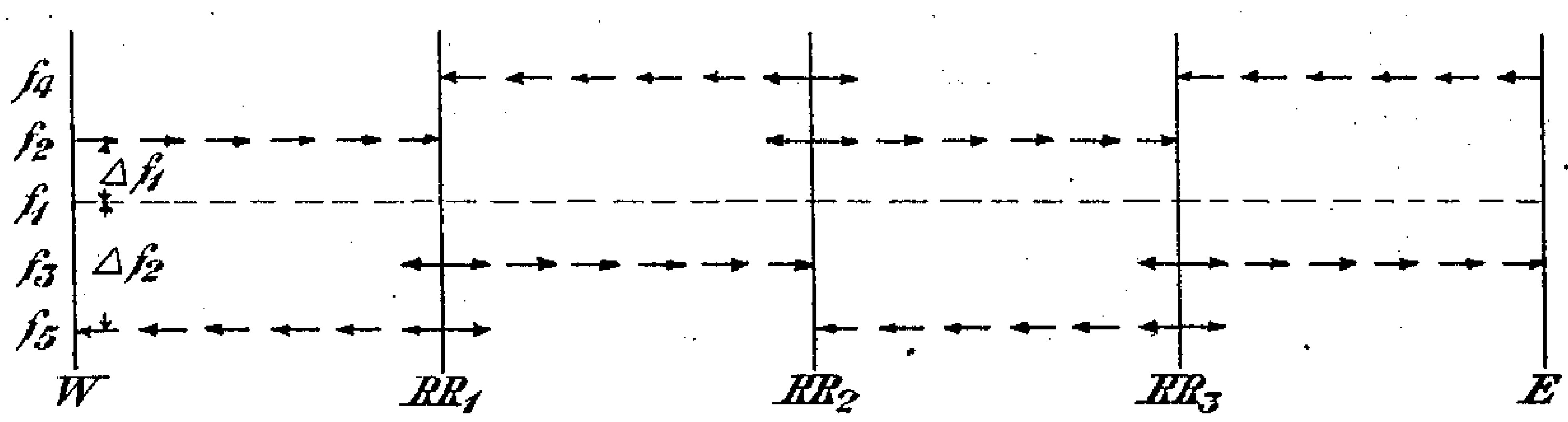

Fig. 3

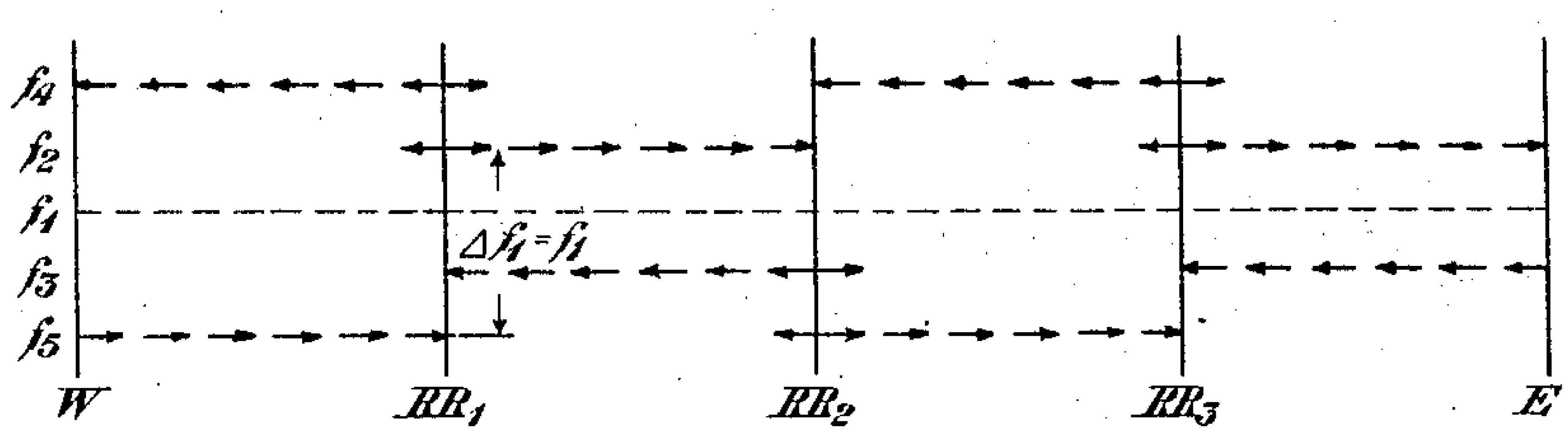

Fig. 4

INVENTOR

D. K. Martin

BY

ATTORNEY

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UNITED STATES PATENT OFFICE.

DE LOSS K. MARTIN, OF WEST ORANGE, NEW JERSEY, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

RADIO REPEATER SYSTEM.

Application filed March 22, 1924. Serial No. 701,186.

This invention relates to radio signaling systems, and particularly to a method and means for operating a system employing one or more repeater stations between the terminal stations thereof, which method is characterized by the changing of the frequencies of the received waves at each repeater station in accordance with a definite plan, whereby singing of individual repeaters or between repeater stations or with a terminal station may be prevented, and whereby the number of frequencies per channel does not exceed a predetermined number irrespective of the number of repeater stations.

In the operation of a long distance radio system having one or more repeaters between the terminal stations thereof, it has heretofore been necessary to change each received frequency of each transmission channel at each repeater to a different frequency in order to prevent currents transmitted from the same repeater from entering the receiving circuits thereof or the receiving circuits of other channels at a distant repeater or terminal station. For a system without repeaters, two frequencies are normally required for each two-way channel, one for transmitting in one direction and another for transmitting in the opposite direction. Considering, for the purpose of illustration, a system of the prior art having two terminal stations and a single repeater therebetween, if we transmit from one terminal a frequency f_1 and from the other a frequency f_2, singing may be prevented only by changing at the repeater the frequency f_1 to a third frequency such as f_3 before radiating it therefrom to the distant terminal to which it is intended to go; and similarly, by changing the frequency f_2 to a fourth frequency such as f_4 before radiating it therefrom. While singing will thereby be avoided both at the repeater station and also with the terminal stations, it is obvious that this result is obtained only by a liberal use of the frequency spectrum since the system requires four frequencies to effect two-way transmission between terminal stations of a system involving only one repeater. If two or more repeaters are included in such a system, the number of frequencies required for the system will, in general, be increased two per channel for each repeater. Obviously, the large demand made upon the frequency spectrum by such a system greatly reduces the field of use of radio repeaters. The applicant has found that by the use of means for controlling the direction of transmission and the reception of waves of the various frequencies and means for changing and selecting the frequencies, it is possible to greatly reduce the number of frequencies required by a multi-repeater radio system below the number given above, namely two per channel per repeater.

In my co-pending application, Serial No. 613,460, filed January 18, 1923, I disclose a method and means for operating a radio communication system involving the use of repeaters, in which system the number of frequencies per channel of communication does not exceed two, regardless of the number of repeaters involved. The system disclosed in the said co-opending application is characterized by the reception at any repeater station of waves from both directions of the same frequency and by transmitting the waves in both directions from the same repeater station at the same frequency, which frequency, however, is different from the reception frequency.

It is the object of the present invention to provide a method and means for effecting two-way communication between two radio stations of a system employing a plurality of repeaters therebetween, the said method being characterized by the reception at any repeater station of waves from both directions at different frequencies and by transmitting from the same station in both directions at different frequencies, the reception frequencies constituting, in effect, one side band of a controlling carrier frequency and the transmitting frequencies constituting the other side band.

The invention will be clearly understood from the following description, when read in connection with the attached drawing, of which Figure 1 shows schematically one form of embodiment of the invention; Fig. 1ª is a modification of part of Fig. 1; Fig. 2 shows directional characteristics of the receiving antennæ of a repeater station, and Figs. 3 and 4 are frequency charts showing the distribution of the frequencies throughout the entire system.

Fig. 1 shows primarily the circuit arrangement in schematic form of one of the repeater stations, as, for example, RR_1, and incidentally the west terminal station and also part of the receiving circuit of the adjacent repeater station RR_2. The west station, which may be of any well-known type, comprises a transmitting antenna TA_1 adapted to transmit, for example, the frequency f_2 of Fig. 3. It may also be designed and adjusted to transmit also the frequency f_1 for controlling the modulation at the various repeater stations. However, it is desirable to point out that a separate transmitting antenna may be used in connection with the system for transmitting the modulating frequency f_1. The west station also comprises a receiving antenna RA_1 which is designed and adjusted for the reception of signals coming from the east. It is to be understood that the terms east and west have been chosen arbitrarily to describe this invention and constitute no limitation thereon.

At the radio repeating station RR_1, each of the receiving antennæ RA_2 and RA_3 is designed and adjusted, in ways well-known to those skilled in the art, for receiving signals efficiently from only one direction. It is well-known that an antenna structure comprising a vertical antenna such as 1 and a loop such as 2 may have directional characteristics such as shown in Fig. 2,—that is to say, by the proper adjustment of the constants of each antenna circuit, and by proper orientation of the loop, the combined structure may be caused to receive most efficiently from only one direction, as shown in Fig. 2. For example, the antenna RA_2 may be adjusted to receive most efficiently from the west,—that is to say, signals transmitted from the antenna TA_1 and the antenna RA_3 may in like manner be adjusted to receive most efficiently from the east,—that is, the frequency transmitted from one of the transmitting antennæ associated with the repeater RR_2. By means of the condensers 3 and 6, the loops 2 and 5 may be properly tuned. M_1, M_2, M_3 and M_4 are modulators in which the received signaling frequencies are beaten with another frequency which may be termed the modulating frequency. This frequency may be received by the antenna R_3, or supplied by a local oscillator as shown in Fig. 1[a]. C indicates a controlling device for controlling the modulating frequency f_1, and A_5 is an amplifier for producing the required degree of amplification to the frequency f_1 before impressing it upon the modulating devices. F_1, F_2, F_3 and F_4 represent band filters and A_1, A_2, A_3 and A_4 represent amplifiers. The output side of the amplifier A_3 is connected with the transmitting antenna TA_2 by means of which oscillations of the frequency f_3 are transmitted and received by the antenna RA_4 of the adjacent repeater station RR_2. The transmitting antenna TA_3 is intended to transmit the oscillations of the frequency f_5 to the antenna RA_1 associated with the west station. The transmitting antennæ, such as TA_1, TA_2, TA_3, etc., as shown, are not directive in the sense in which the word "directive" is normally used in the art, but antenna arrangements to give directive transmission may be used with equal effectiveness in the operation of this system.

Let it be assumed that oscillations of the frequency f_1 are being transmitted from the antenna TA_1 or by another antenna of the system and are being received by the antenna R_3 associated with the repeater station RR_1 and also by similar antennæ of the other repeater stations, or that the oscillations are supplied locally by means of an oscillation generator as in Fig. 1[a]. These oscillations amplified by A_5 will be impressed upon the modulators M_1 to M_4, inclusive. Simultaneous with the reception of the modulating frequency f_1, oscillations of the frequency f_2 transmitted by TA_1 will be received by the antenna RA_2 and will thereby be impressed upon the modulator M_1. Oscillations of the frequency f_2 will also be impressed upon the antenna RA_3, but since this antenna circuit is designed and adjusted to receive efficiently only from the opposite direction, that is, from the east, substantially no current will be impressed thereby upon the modulator M_2. The current of the frequency f_2 impressed upon the modulator M_1 will be beaten therein with the frequency f_1 and the difference frequency will be selected by the filter F_1, which difference frequency, after being amplied by the amplifier A_1, will be impressed upon the modulator M_3. This difference frequency will be beaten in the modulator M_3 with the frequency f_1 and the difference frequency will be selected by the filter F_3 and impressed upon the amplifier A_3. This frequency designated f_3, when amplified, will be radiated by the antenna TA_2 and will be received by the antenna RA_4 of the repeater station RR_2, which is designed for efficient reception from the west. Since this may be more clearly understood by assigning specific values to the various frequencies, it will be assumed for the purpose of description that the frequency f_2 transmitted from the west station is 700 kilocycles and that the modulating frequency f_1 is 650 kilocycles. The difference frequency selected by the filter F_1 is 50 kilocycles. This frequency, when beaten with 650 kilocycles in the modulator M_3, produces two frequencies, 700 and 600 kilocycles, respectively. The latter frequency is selected by the filter F_3 and is transmitted to the station RR_2. Let us assume that the transmitting antenna TA_5 of repeater station RR_2 is transmitting the frequency f_4 which will be assumed to be 750 kilocycles. This frequency will be received at station RR_1 by the antenna RA_3 designed for efficient reception from the east and will be beaten in the modulator M_2 with the modulating frequency of 650 kilocycles. The difference frequency, namely 100 kilocycles, will be selected by the filter F_2 and after amplification by A_2, will be impressed upon the modulator M_4. Herein this difference frequency of 100 kilocycles will be beaten with the modulating frequency of 650 kilocycles producing 750 and 550 kilocycles. The difference frequency, namely 550 kilocycles, will be selected by the filter F_4 and after amplification by A_4, will be radiated by the antenna TA_3. This frequency, designated on the drawing as f_5, will be received by the receiving antenna RA_1 of the west station, which is designed for efficient reception from the east, and will be impressed upon receiving apparatus at that station.

Fig. 3 shows that the frequency f_2 transmitted from the west station, becomes f_3 at the first repeater station and is translated back to f_2 at the second repeater station, and again translated to f_3 at the third repeater station, from which it is received by the east terminal station. In a similar manner, the transmitting frequency f_4 from the east station becomes f_5 at the third repeater station, thence changing to f_4 at the second repeater station and finally becoming f_5 at the first repeater station, from which it is transmitted to the west terminal station. It will be seen from this frequency distribution diagram that at any repeater station the received currents are upon one side of the modulating frequency f_1 and the transmitted frequencies from the same repeater station are upon the opposite side of this modulating frequency. By separating the frequencies in this manner, the transmitted frequencies from any station will not affect the receiving circuits of the same station, and by using direction-controlled receiving antennæ at each of the repeating stations and the terminal stations, the transmitted frequencies from any station will not produce singing between the said repeater stations or between a repeating station and a terminal station.

While the means herein disclosed for carrying out this invention is substantially that shown in the co-pending application referred to above, the method of operating the system which constitutes the present invention differs from that described in the co-pending application in that it consists in receiving at each repeater station waves of different frequencies and in transmitting therefrom waves of different frequencies. But it is to be noted that both of the received frequencies are within one side band and the transmitted frequencies are also within one side band, which side bands, however, are opposite.

It is desired to clearly set forth that while reference has been made throughout the description of my invention of the use of a single frequency, as, for example, f_2 or f_3, as representing the transmitted or received frequencies constituting a transmission channel, it is to be understood that the designation of these channels by single frequency waves is for the purpose of rendering the description simple and therefore clear, but it is not to be construed as limiting the invention in any way to transmission or reception upon a single frequency. The transmitted and the received waves of each channel may, of course, be a side band of frequencies produced by the modulation of a carrier frequency by the frequencies within the voice range, such as is done in radio telephony, or by the modulation of a carrier frequency by telegraph frequencies, such as is employed in radio telegraphy.

While this invention has been disclosed as embodied in a particular form and arrangement of parts, it is not so limited but is capable of embodiment in other forms without departing from the spirit and scope of the appended claims.

What is claimed is:

1. In a radio repeating system having terminal stations and a plurality of repeater stations located therebetween in which two-way signaling is effected by using at each repeater station a transmitting wave of different frequency from the receiving wave, the method for limiting the number of frequencies used throughout the system for each channel of communication to four regardless of the number of repeaters involved, which consists in receiving by directional selection at each repeater station east and west waves of different frequencies, separately beating each wave with the same carrier frequency, the said carrier frequency being so chosen as to change the frequency of one of the said received waves by double the amount by which the other received wave is therein changed, and transmitting both of said waves as thus changed.

2. In a radio repeating system having terminal stations and a plurality of repeater stations located therebetween, in which two-way signaling is effected by using at each repeater station a transmitting wave of different frequency from the received wave, the method of limiting the number of frequencies used throughout the system for each channel of communication to four, regardless of the number of repeaters involved, which consists in receiving by unidirectional selection at each repeater station, east and west waves of different frequencies, changing the frequency of each of the said

received waves, the frequency change of one of the received waves being different from that of the other, and transmitting both of the said waves as thus changed.

3. In a radio repeating system having terminal stations and a plurality of repeater stations located therebetween in which two-way signaling is effected by using at each repeater station a transmitting wave of different frequency from the receiving wave, the method for limiting the number of frequencies used throughout the system for each channel of communication to four regardless of the number of repeaters involved, which consists in receiving by directional selection at each repeater station east and west waves of different frequencies, separately beating each of the said waves with a third frequency, selecting the difference frequencies produced thereby, separately beating the said difference frequencies with the said third frequency, selecting the difference frequencies produced thereby, and transmitting the latter selected frequencies.

In testimony whereof I have signed my name to this specification this 20th day of March, 1924.

DE LOSS K. MARTIN.