March 25, 1930. E. I. GREEN 1,751,516

COMMON FREQUENCY BROADCASTING SYSTEM

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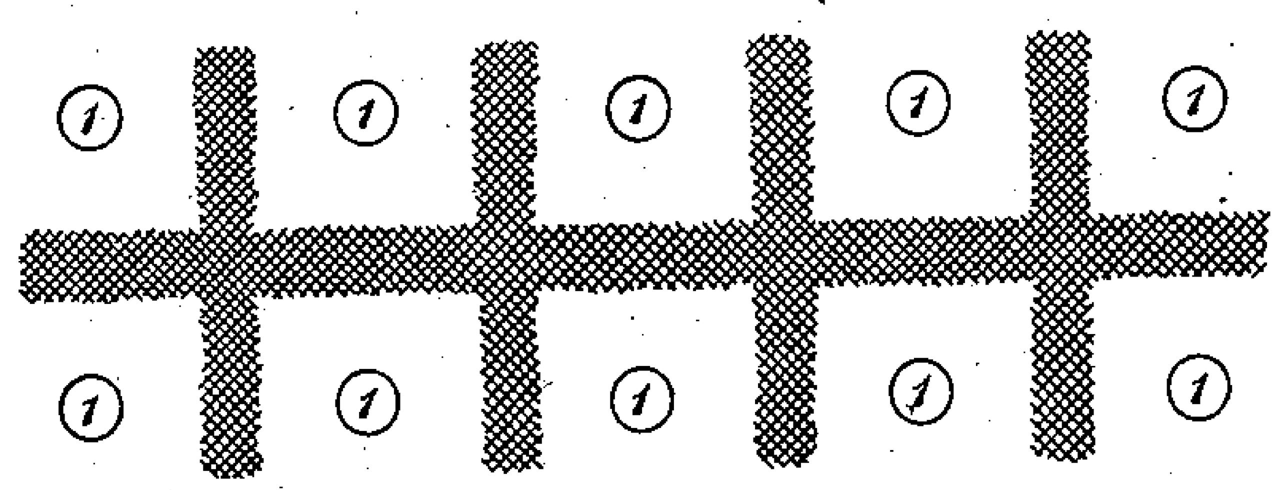

Fig. 1 - Single Frequency Arrangement

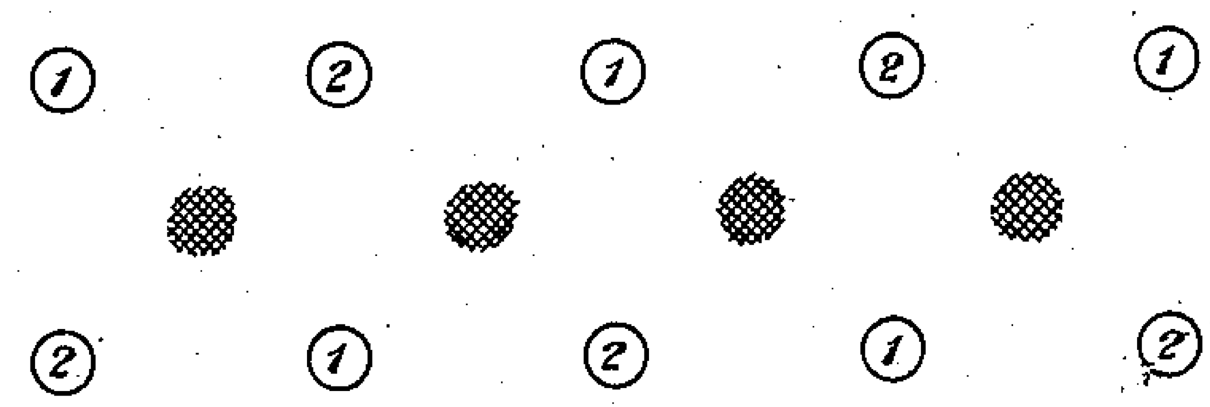

Fig. 2 - Two Frequency Arrangement

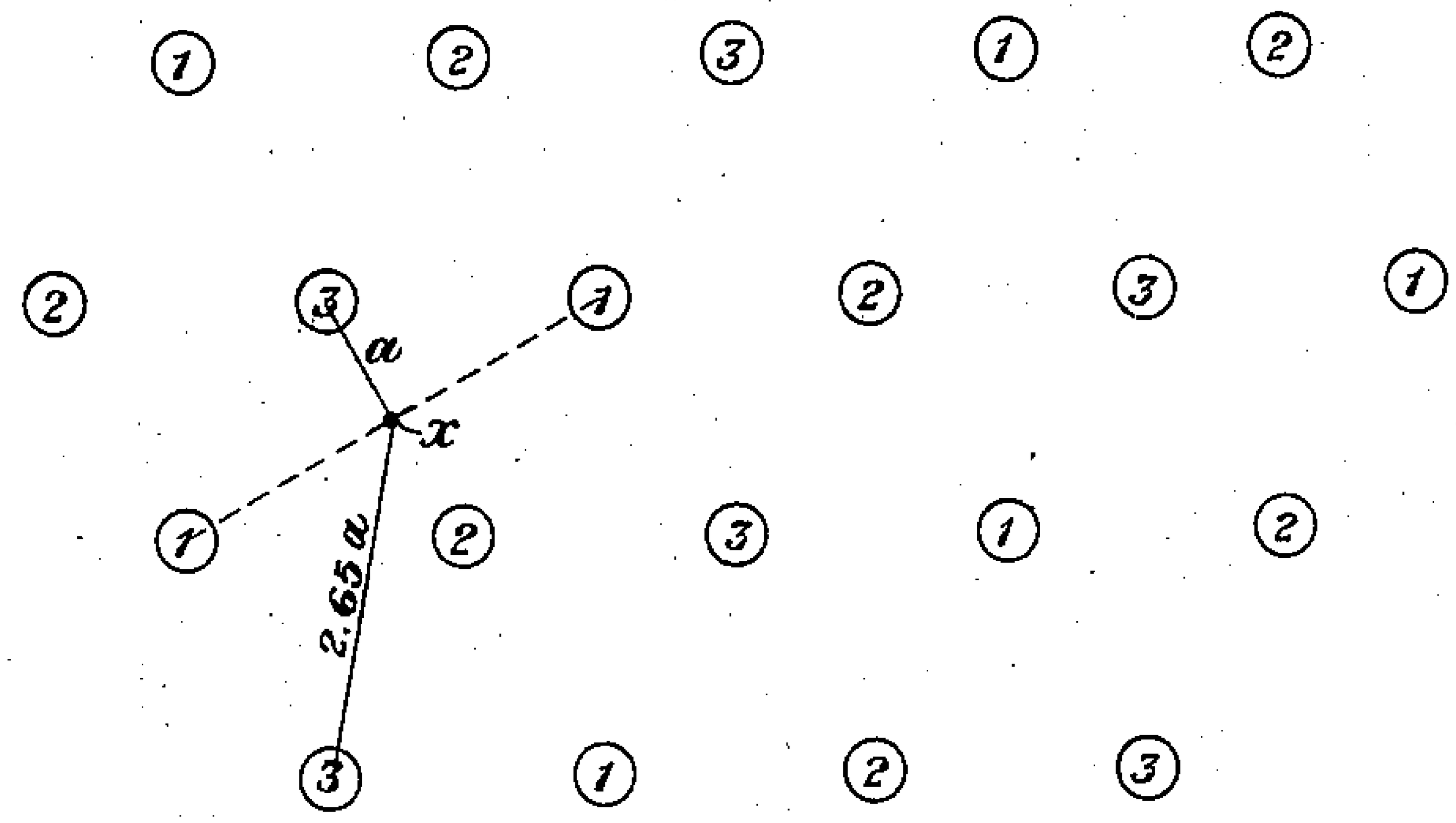

Fig. 3 - Three Frequency Arrangement

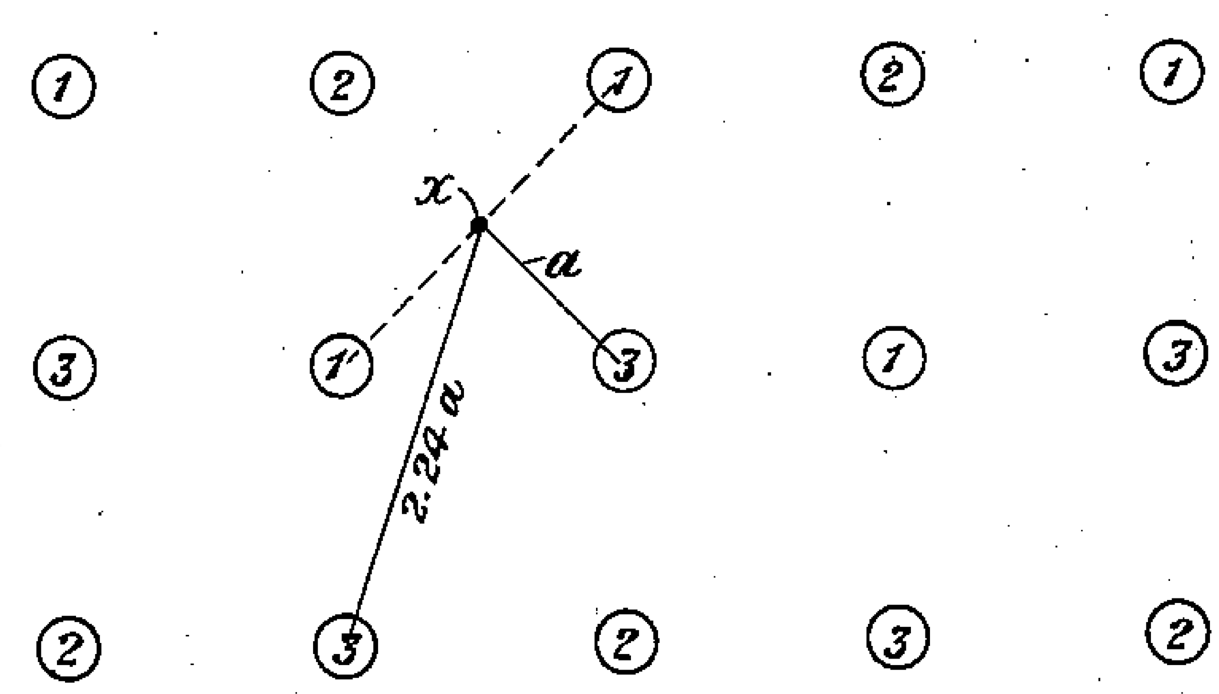

Fig. 4 - Three Frequency Arrangement

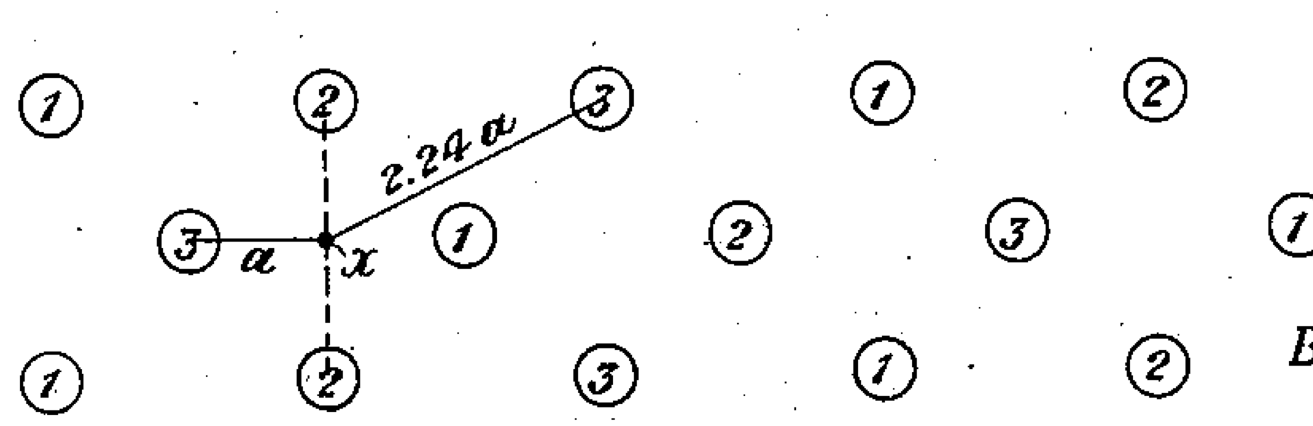

Fig. 5 - Three Frequency Arrangement

INVENTOR.
E. I. Green
BY
[signature]
ATTORNEY

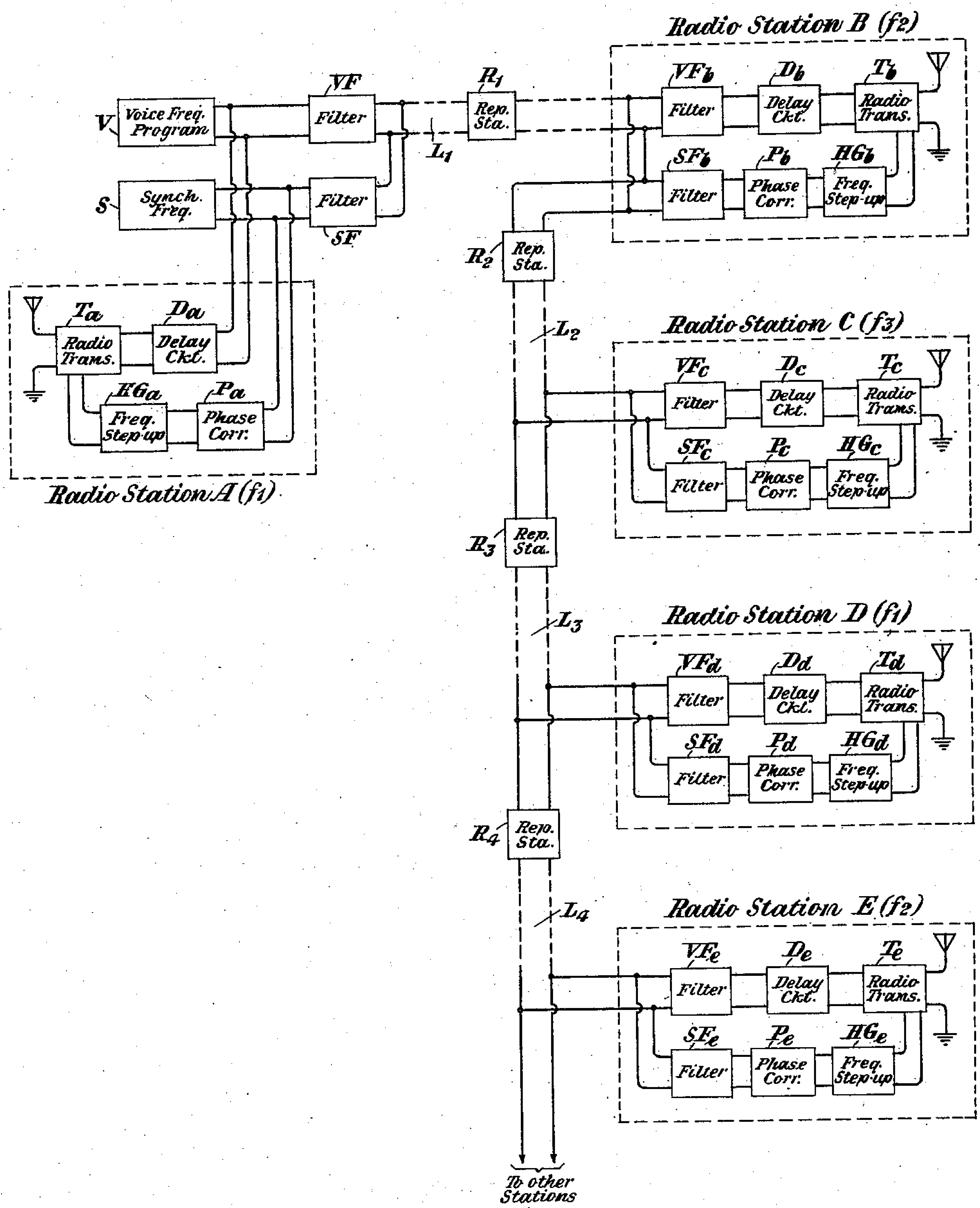

Fig. 6

Detailed Arrangement for Multi-Frequency System

INVENTOR.
E. I. Green
BY
[signature]
ATTORNEY

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UNITED STATES PATENT OFFICE

ESTILL I. GREEN, OF EAST ORANGE, NEW JERSEY, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK

COMMON-FREQUENCY BROADCASTING SYSTEM

Application filed August 8, 1927. Serial No. 211,518.

This invention relates to systems for broadcasting programs by means of radio stations, and, more particularly, to systems in which a plurality of radio stations are arranged to broadcast simultaneously at the same wave length.

In order to conserve the available frequency range, it has heretofore been proposed that a number of broadcasting stations be arranged to operate on a common frequency. Such arrangements have been tried out to some extent, and while they appear to be in general practicable, they have been found to have certain limitations. For example, where a chain of radio stations are broadcasting at a common wave length, there will be a certain number of listeners who are so located with respect to the stations as to receive similar field strength from two stations, so that interference results.

In general, two different cases of interference in a common frequency broadcasting system may arise, namely, interference where two stations transmit different programs but on a common wave length, and interference arising where the stations not only broadcast at a common wave length, but broadcast the same program. In either of these cases, a listener located in a zone where the field strength of the two nearest stations has the same order of magnitude will experience substantial interference between the signals from the two stations. For normal transmission conditions and equal power at the two broadcasting stations, this interference zone would obviously lie approximately midway between stations.

This interference may take several different forms. If the carrier frequencies of the two stations are not accurately synchronized, audible beat notes may be produced between the two carrier frequencies. Furthermore, even though the carrier frequencies be kept sufficiently close together to avoid audible beats, there will be, in the case of stations broadcasting different programs at the same wave length, considerable difficulty, due to cross-talk between the two different programs. In the case of stations broadcasting the same program, there will be a pulsating or fluctuating effect if the difference between the two carrier frequencies is a few cycles, or slow fading if the carrier frequencies are more accurately synchronized.

In accordance with the present invention, it is proposed to overcome these difficulties by employing several broadcasting frequencies, each common to a number of stations, the stations being so physically located with reference to each other that where a receiver is located in an interference zone between two stations transmitting on the same wave length, reception will be possible from another broadcasting station employing a different wave length, without substantial interference from another station also employing such different wave lengths. While the invention is applicable to a chain of broadcasting stations employing the common wave lengths, whether they transmit the same or different programs, it is more particularly applicable to the situation in which the same program is transmitted.

The invention may now be more fully understood from the following detailed description when read in connection with the accompanying drawing, Figure 1 of which shows symbolically a lay-out of broadcasting stations all transmitting at the same wave length and thereby producing interference zones between stations; Fig. 2 of which is a lay-out of broadcasting stations, in accordance with the present invention, and employing two different frequencies, so that the zone of interference between the stations is greatly reduced; Figs. 3, 4 and 5 of which represent different lay-outs employing three frequencies in such a manner as to entirely eliminate all interference zones between stations; and Fig. 6 of which represents schematically a circuit arrangement whereby a plurality of broadcasting stations may be interconnected in accordance with the present invention to broadcast the same program on a plurality of wave lengths, each wave length being employed in common by several stations.

Referring to Fig. 1, small circles represent broadcasting stations arranged generally in rows. The numeral 1 applied to each circle indicates that each broadcasting station so designated employs the same carrier frequency. In such an arrangement, if we consider a receiver located between the first and second stations at the left of the upper row, it will be apparent that interference will occur. Likewise, considering the first station at the left in the upper row, and the second station from the left in the lower row, there will be interference in a receiver located substantially midway between the two stations. In general, interference zones may be expected to occur over the cross-hatched areas of Fig. 1.

By using two different frequencies and assiging one or the other of these frequencies to the stations, as indicated in Fig. 2, the interference zones will be reduced to very small areas. In this figure, all of the stations marked 1 are transmitting at one common wave length, and all of the stations marked 2 are transmitting at another common wave length. It is to be noted that alternate stations employ different frequencies. The theory underlying this arrangement is that a receiver located in a zone where interference might be expected between two stations using the same frequency may be tuned to the other frequency provided by the arrangement, in which case the receiver will not in general receive equal signal intensities from the two nearest stations employing the alternate frequency. From a consideration of the arrangement of Fig. 2, however, it is apparent that although the situation has been greatly improved, there still remain certain small regions in which the listener would receive two signals of approximately the same intensity from the two nearest stations, regardless of whether he tunes his receiver to the one wave length or the other. For example, a receiver located midway between the first two stations at the left in the upper row may receive the program by tuning either to the first or to the second wave length, without interference, although the receiver is substantially equi-distant between the two nearest stations. The same would be true for a receiver located between the extreme left-hand stations of the upper and lower rows, or for a receiver located between the stations second from the left in each of the rows, etc. In the case, however, of a receiver located about midway between a group of four adjacent stations, such, for example, as the group comprising the first and second stations from the left in the two rows, interference would occur, whether it was tuned to the first wave length, or the second. Such a receiver would be substantially equi-distant from the two nearest stations employing the first wave length, and also substantially equi-distant between the two nearest adjacent stations employing the second wave length.

By employing three different frequencies for the system, it will be possible, by properly locating the stations, and properly assigning the frequencies to the stations, to entirely avoid the presence of any zones of interference. In fact, theoretical considerations indicate that three frequencies constitute the minimum number with which such a condition is possible. One such an arrangement is illustrated in Fig. 3. Here, the broadcasting stations are arranged substantially in rows, with stations in any row staggered with respect to the stations in an adjacent row. The numerals 1, 2 and 3, applied to the stations, indicate that those stations designated by the numeral 1 broadcast at one common wave length, those designated by the numeral 2 at a second common wave length, and those designated by the numeral 3 at a third common wave length. If we consider any group of four nearest adjacent stations, surrounding a common area, it will be seen that while two of them employ the same wave length, the other two will employ different wave lengths. Therefore, any listener in the interference zone between the two stations employing the same wave length may tune his receiver to one or the other of the two remaining stations without substantial interference. For example, take the first and second stations from the left in the upper two rows. A listener midway between the first station from the left in the second row, and the second station from the left in the top row would be in an interference zone with reference to these two stations which broadcast at the same frequency. By tuning to the frequency of the first station at the left in the top row, or by tuning to the second station from the left in the second row from the top, such a listener should be able to receive a program from either of these stations without substantial interference. So, also, if we consider a listener located at the point x in Fig. 3, it will be apparent that such listener will be midway between two adjacent stations, both broadcasting at frequency No. 1. If he tunes to frequency No. 3, which is employed by the second station from the left in the second row from the top, the nearest station transmitting at this same wave length will be the first station at the left in the lower row. It may be shown geometrically that the distance from the listener to the last-mentioned station is approximately 2.65 times as great as the distance from the listener to the second station from the left in the second row from the top. The listener would therefore be quite favorably located with reference to the nearest station employing frequency No. 3, and would not be sufficiently close to any other station employing the same wave length to meet with any considerable degree of interference.

An alternative arrangement, employing three frequencies, is illustrated in Fig. 4.

Here, the stations are located substantially in rows, both vertically and horizontally. Two frequencies are employed for the stations of each horizontal row, so that successive stations broadcast at alternate frequencies. Successive stations in each vertical row, however, employ different ones of three frequencies. Here, again, if we consider any group of four nearest stations surrounding a common area, it will be seen that only two of the four stations employ the same wave length. Any listener, in this common area, who is substantially equi-distant between the two stations employing the same wave length may, however, tune to either of the other stations without material interference. Any listener in the common area, who is not substantially centrally located with respect to the four stations, may tune his receiver to any one of the three frequencies employed in the system, without substantial interference. Consider, for example, a listener located at x. Such a listener, by tuning his receiver to frequency No. 1, would encounter interference between the third station from the left in the top row, and the second station from the left in the second row. If, however, he should tune his receiver to frequency No. 3, the nearest station broadcasting at that frequency will be the third station from the left in the second row. The next nearest station broadcasting at this frequency will be the second station from the left in the lower row, which station is geometrically located approximately 2.24 times as far from the station x as is the third station from the left in the second row. Therefore the listener at x should not encounter material interference at the third frequency. In a similar manner, he can tune to frequency No. 2 without encountering any greater degree of interference than in the case of frequency No. 3.

Still another arrangement, employing three frequencies, is illustrated in Fig. 5. Here, as in Fig. 3, the transmitting stations are arranged approximately in rows, with the stations in alternate rows staggered with respect to those in the adjacent rows. The arrangement of Fig. 5 differs from that of Fig. 3 principally in the fact that the triangle formed by any three adjacent stations is substantially a right angle triangle rather than substantially an equilateral triangle. Here, again, if we consider any group of four adjacent stations surrounding a common area, it will be seen that not more than two of them transmit at the same carrier frequency. If we consider a listener located at x, such a listener will be substantially equi-distant with respect to the second station from the left in the upper row and the lower row, and will therefore meet with interference from those stations, each of which will be transmitting at frequency No. 2. Such a listener may tune his set to either frequency No. 3, or frequency No. 1. If he tunes to frequency No. 3, for example, it will be seen that the nearest station transmitting at that frequency is the first station at the left in the middle row. The next nearest station is the third station from the left in the upper row, and it may be shown geometrically that the latter station is approximately 2.24 times as far from station x as is the first station at the left in the middle row.

It will be understood that the arrangements above described represent ideal locations of a group of broadcasting stations. In practice, it will be necessary, due to local conditions, to depart, to some extent, from any one of the above schemes which might be chosen. Nevertheless, it should be possible, in any practical case, to arrive at a sufficient approximation of one of the above ideal arrangements to insure that a listener located at any point will be able to receive a signal from at least one station of the four nearest stations without undue interference. It will also be understood that other arrangements of stations and frequency allocations following the same general principles may be made, if desired, those above described being merely used for purposes of illustration.

While the invention is not limited to any particular arrangement for linking the stations together, and for controlling the carrier frequencies employed by the stations, an arrangement for accomplishing the desired results is illustrated in Fig. 6. In this figure, a group of stations A, B, C, D, E, etc., are so linked together as to broadcast the same program, utilizing three different carrier frequencies for the entire system. The voice frequency program originates at V, and a synchronizing frequency is generated at S. The synchronizing frequency is impressed upon a frequency step-up arrangement HG_a at the local radio station A to generate a carrier frequency f_1. The frequency step-up arrangement may be, for example, a harmonic generator, of known type, upon which the synchronizing frequency may be impressed, together with a selective device to select the desired harmonic of the synchronizing frequency. The desired harmonic is then impressed upon the radio transmitter T_a. The frequency step-up device may also include suitable amplifying means, if necessary. The program from V is also impressed upon the radio transmitter T_a to modulate the selected carrier frequency.

The program originating at V, and the synchronizing frequency originating at S, may also be applied to a transmission line L_1 through filters VF and SF. The line L_1 may include one or more repeaters, such as R_1, and serves to transmit the program and synchronizing frequencies to station B. Here, the program and synchronizing frequencies are selected through filters VF_b and SF_b, respectively, and impressed upon a radio transmitter T_b, the synchronizing frequency being stepped up by means of a frequency step-up device HG_b to the desired radio frequency for station B, which may be assumed to be a frequency f_2.

The program and synchronizing frequencies are transmitted from the station B over a line L_2 (which may include a repeater or repeaters R_2) to a station C, which is provided with equipment similar to that at station B, except that here the frequency step-up device HG_c steps up the synchronizing frequency to a carrier frequency f_3.

Similarly, the program and synchronizing frequencies may be transmitted over other line circuits such as L_3, L_4, etc., to other stations, such as D, E, etc., where additional carriers f_1, f_2, etc., may be generated.

In order that the program may be impressed upon each radio transmitter at exactly the same time, regardless of the length of line over which the program is transmitted, delay circuits, such as D_a, D_b, etc., are interposed in the program connection leading to each radio transmitter, these delay circuits being so designed that the over-all transmission time from the program source to each radio station will be the same. Phase correcting devices, such as P_a, P_b, etc., are also provided at each transmitting station in the connection leading to the frequency step-up device for the purpose of adjusting the phase of the arriving synchronizing frequency, so that it arrives at each station in the same phase relation. The delay circuits and phase correctors may be of any known type. For example, a delay circuit may be a network of the Campbell filler type, and the phase corrector may be anything from a simple, adjustable condenser to a more complicated adjustable network for phase correction.

It will 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 chain broadcasting system, a plurality of broadcasting stations arranged to transmit the same program, each station transmitting on but a single wave length, said stations being arranged in groups, each station of a group transmitting at the same wave length, but more than one transmitting wave length being employed for different groups and all of the groups simultaneously transmitting the same program, the stations of the different groups being so located with respect to each other and the stations of other groups, and the wave lengths being so assigned to the stations, that any set of four closely adjacent transmitting stations surrounding a common area will employ less than four but not less than two carrier frequencies.

2. In a chain broadcasting system, a plurality of broadcasting stations arranged to transmit the same program, each station transmitting on but a single wave length, said stations being arranged in groups, each station of a group transmitting at the same wave length, but more than one transmitting wave length being employed for different groups and all of the groups simultaneously transmitting the same program, the stations of the different groups being so located with respect to each other and the stations of other groups, and the wave lengths being so assigned to the stations, that any set of four closely adjacent transmitting stations surrounding a common area will employ less than four but not less than three wave lengths.

3. In a chain broadcasting system, a plurality of broadcasting stations arranged to transmit the same program, each station transmitting on but a single wave length, said stations being arranged in groups, each station of a group transmitting at the same wave length, but more than one transmitting wave length being employed for different groups and all of the groups simultaneously transmitting the same program, the stations of the different groups being so located with respect to each other and the stations of other groups, and the wave lengths being so assigned to the stations, that of any set of four closely adjacent transmitting stations surrounding a common area, certain stations of the set will employ the same wave length but not more than two will employ the same wave length.

4. In a chain broadcasting system, a plurality of broadcasting stations arranged to transmit the same program, each station transmitting on but a single wave length, said stations being arranged in groups, each station of a group transmitting at the same wave length, but more than one transmitting wave length being employed for different groups and all of the groups simultaneously transmitting the same program, the stations of the different groups being so located with respect to each other and the stations of other groups, and the wave lengths being so assigned to the stations, that of any set of four closely adjacent transmitting stations surrounding a common area, certain stations of the set will employ the same wave length but not more than two will employ the same wave length, and the other two stations of the set will employ different wave lengths.

5. In a chain broadcasting system, a plurality of broadcasting stations each transmitting on a single wave length and arranged substantially in rows, and a plurality of transmitting wave lengths simultaneously carrying the same program being so assigned to the

stations that certain stations of all of the rows employ the same transmitting wave length, and certain other stations of all the rows employ different transmitting wave lengths, the wave lengths being also so assigned to the stations that any station in a given row will transmit on a frequency different from the transmitting frequency of the nearest adjacent station in the same row, and from the transmitting frequency of the nearest adjacent station in the nearest adjacent parallel row.

In testimony whereof, I have signed my name to this specification this 2nd day of August, 1927.

ESTILL I. GREEN.