TRANS ONLY (SYNC) NO Recvr 455/6

Examiner

May 7, 1929. L. ESPENSCHIED ET AL 1,711,560

RADIO BROADCASTING SYSTEM

Filed Aug. 27, 1926 3 Sheets-Sheet 1

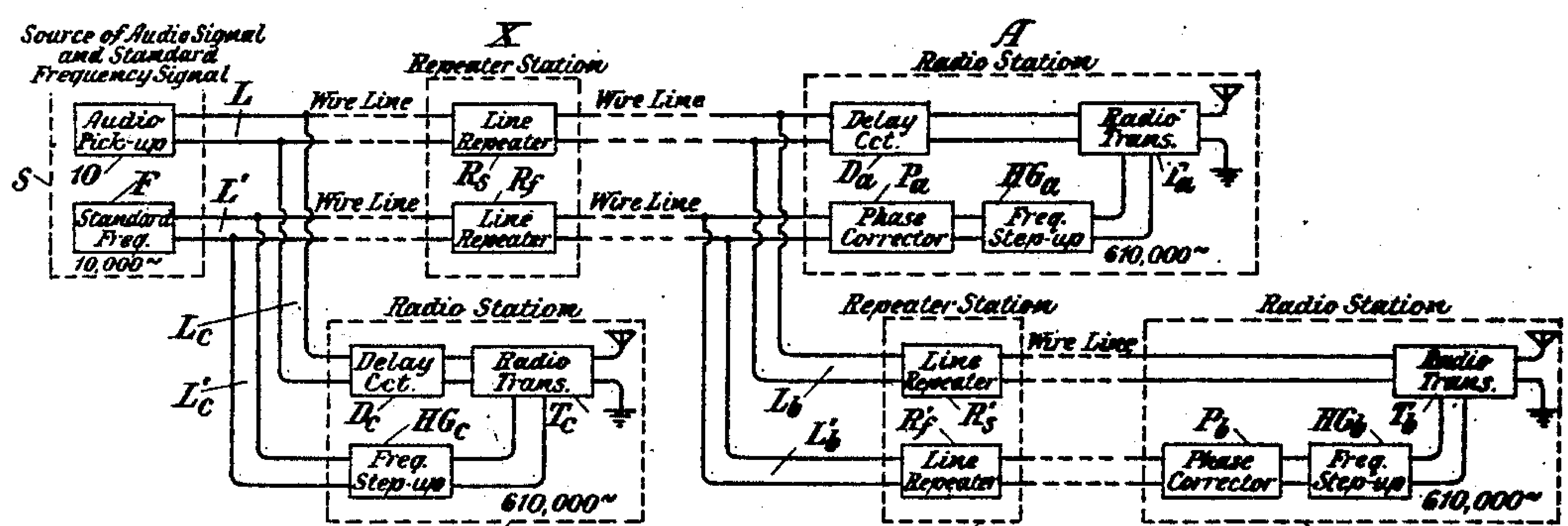

Fig. 1

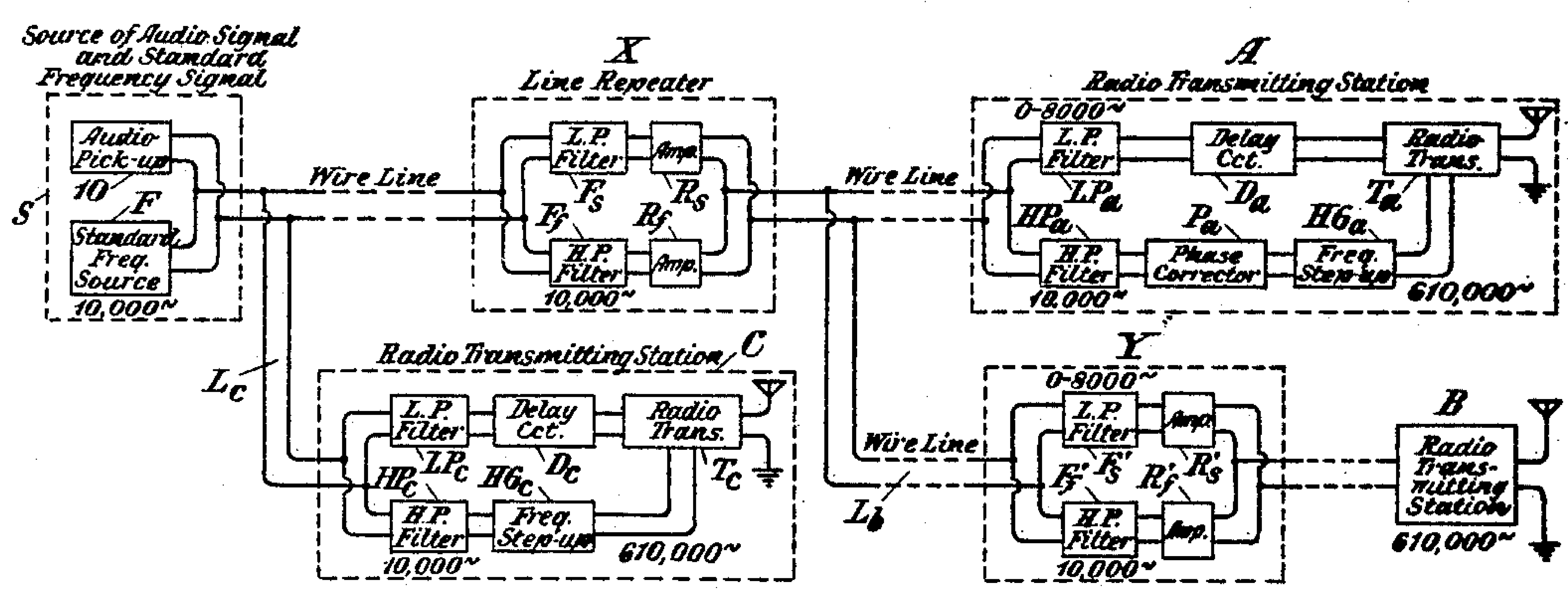

Fig. 2

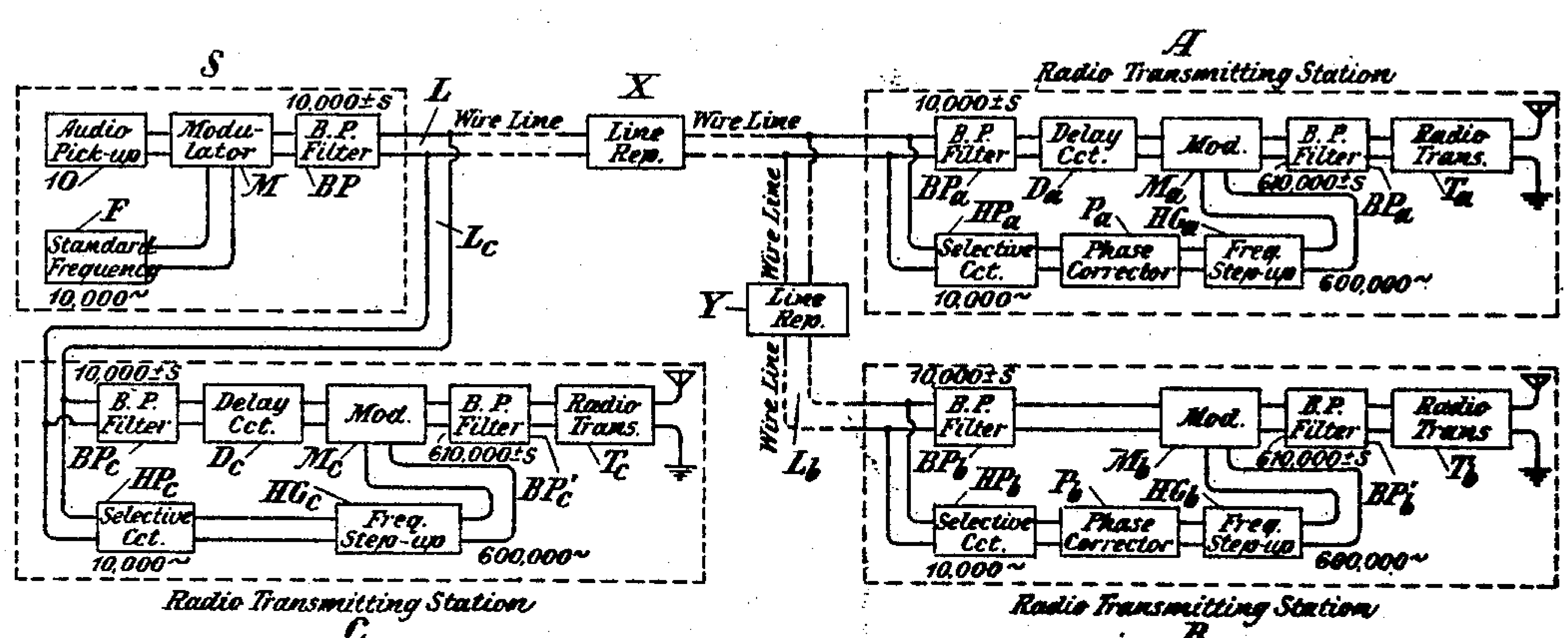

Fig. 3

INVENTORS
L. Espenschied, R. Bown and
D. K. Martin
BY
ATTORNEY

May 7, 1929. L. ESPENSCHIED ET AL 1,711,560

RADIO BROADCASTING SYSTEM

Filed Aug. 27, 1926 3 Sheets-Sheet 2

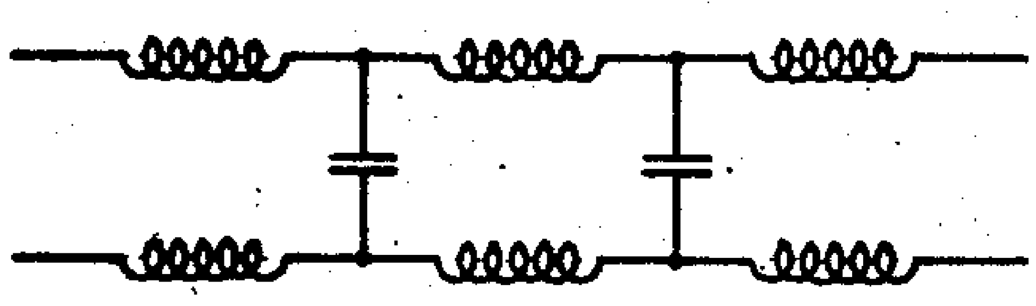

Fig. 4

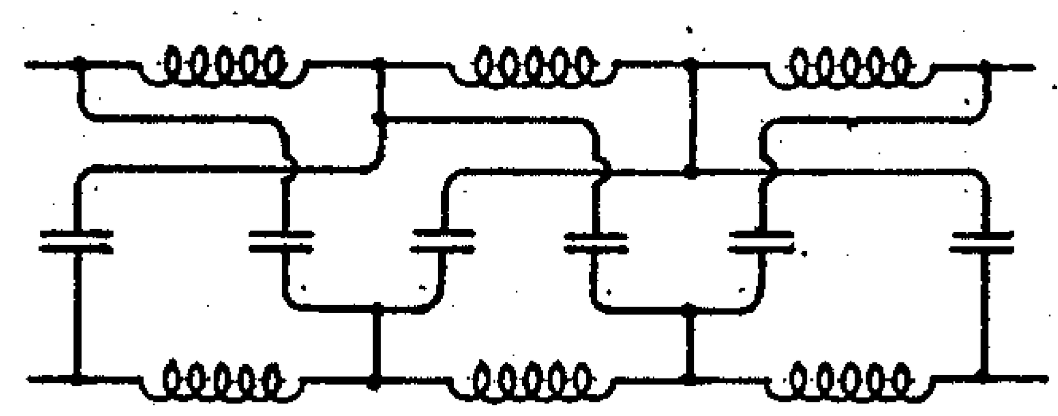

Fig. 5

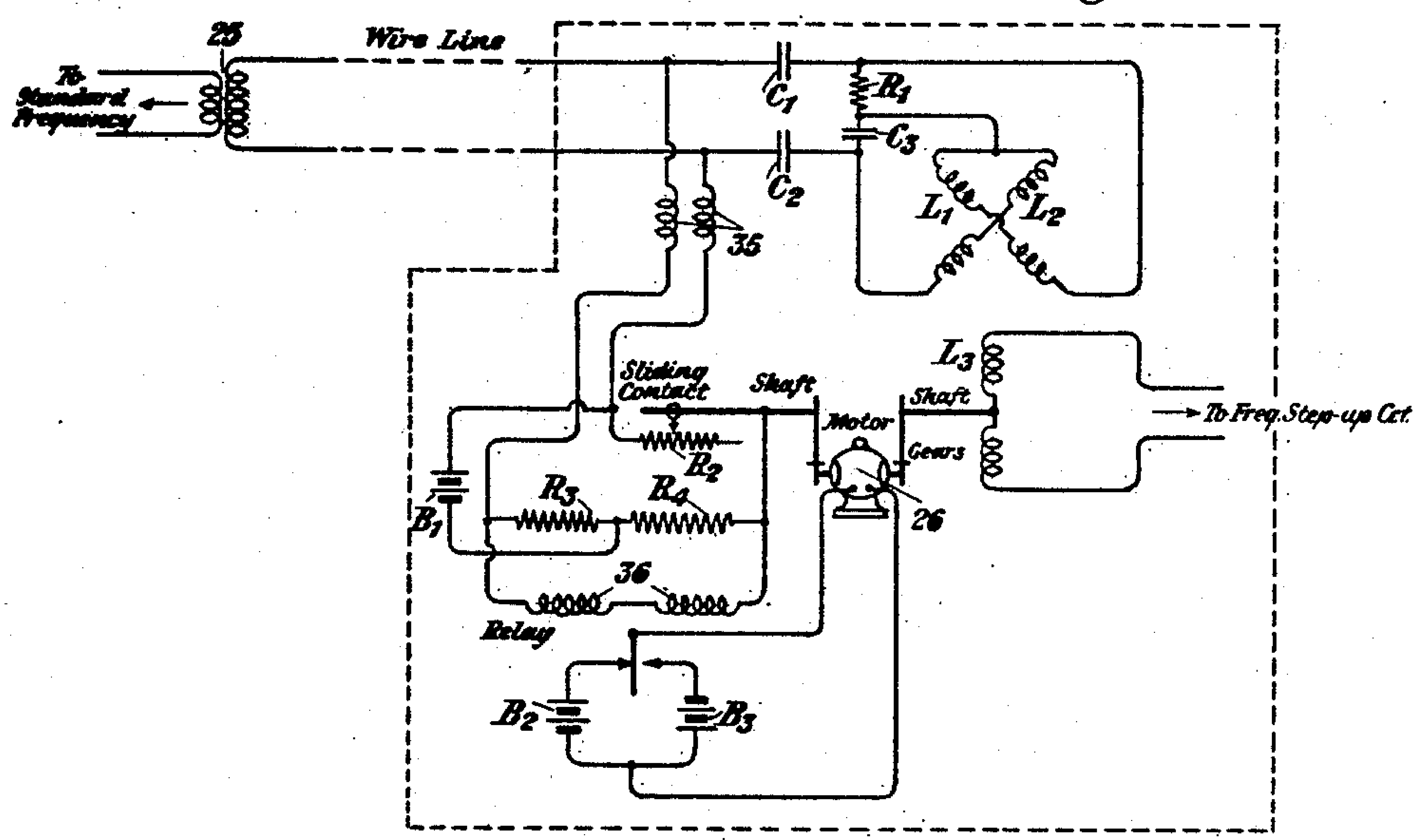

Fig. 6

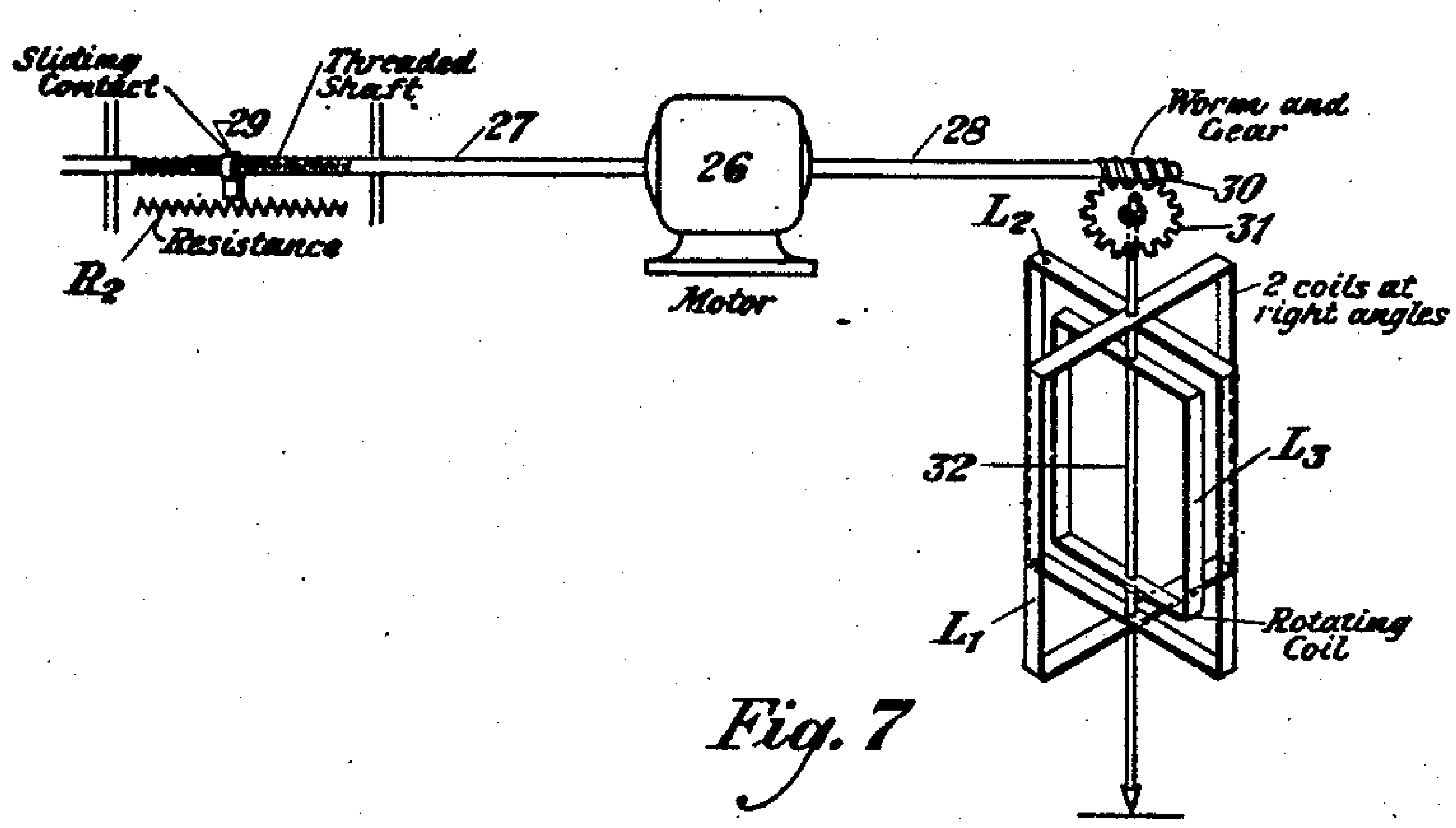

Fig. 7

INVENTORS
L. Espenschied, R. Bown and D. K. Martin
BY
ATTORNEYS.

260. RADIANT ENERGY.

Examiner

May 7, 1929. L. ESPENSCHIED ET AL 1,711,560

RADIO BROADCASTING SYSTEM

Filed Aug. 27, 1926 3 Sheets-Sheet 3

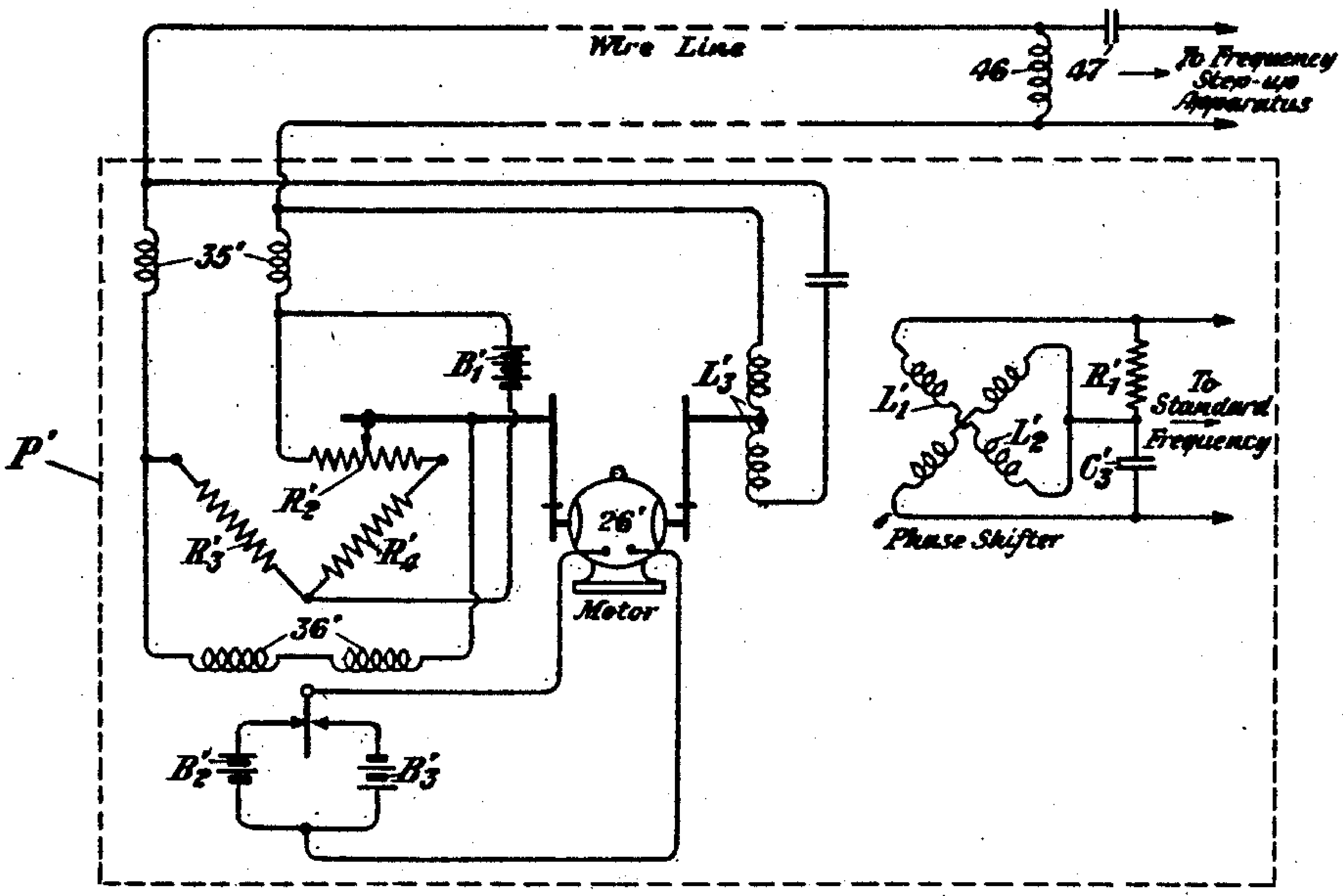

Fig. 8

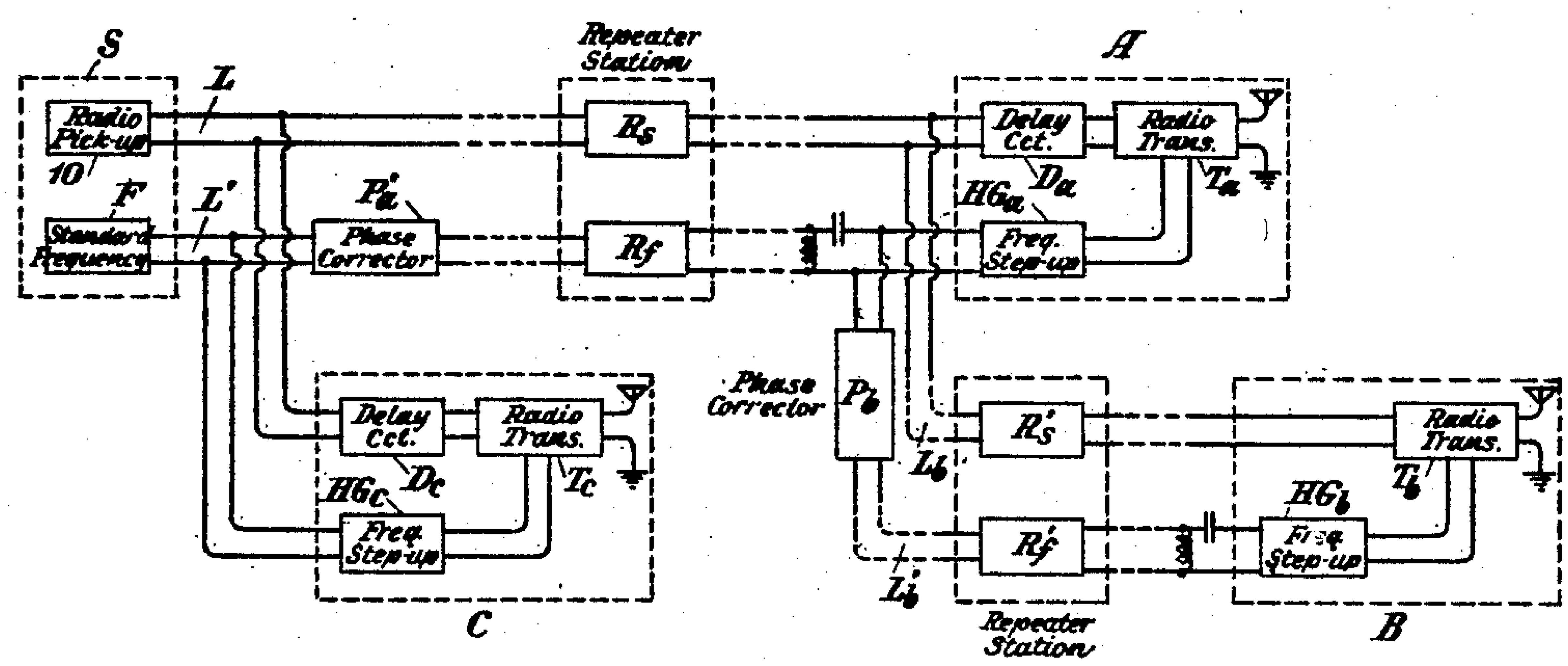

Fig. 9

INVENTORS

L. Espenschied, R. Bown

BY D. K. Martin

ATTORNEYS.

Examiner

Patented May 7, 1929. 1,711,560

UNITED STATES PATENT OFFICE.

LLOYD ESPENSCHIED, OF HOLLIS, NEW YORK, AND RALPH BOWN, OF MAPLEWOOD, AND DE LOSS K. MARTIN, OF WEST ORANGE, NEW JERSEY, ASSIGNORS TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

RADIO BROADCASTING SYSTEM.

Application filed August 27, 1926. Serial No. 132,006.

This invention relates to radio broadcast systems, and more particularly a system in which a number of transmitting stations are arranged to broadcast the same program upon the same wave length.

In the expansion of radio broadcast service, where the program is broadcast simultaneously from a number of radio stations transmitting on different wave lengths, it immediately becomes apparent that a considerable part of the band of frequencies available for broadcasting has been monopolized in the transmission of a single program. It is therefore desirable to be able to broadcast from each of the stations at the same wave length. The solution of this problem, however, presents a number of technical difficulties. Depending upon the relative power transmitted, stations approximately 100 miles or more apart, broadcasting the same program, could transmit on the same wave length without producing serious distortion in their signal distribution characteristic within their effective range area. Distortion of the signal distribution characteristic would, however, result from interference between the waves from all the stations transmitting on the common wave length. At points close to any given transmitting station, the amplitude of the signal from that station would be large as compared with the amplitude of the signal from any of the remote stations, and the effect of wave interference would be negligible. At points which are equally distant from any two of the stations, a signal may or may not be received, depending upon the phase and amplitude of the waves at that point. If the waves are in phase, a signal will be received, but if they are out of phase and equal in amplitude, no signal will be received. Since a common program is being transmitted from a group of stations for the purpose of delivering a stronger signal to the maximum number of listeners, and since the listeners are more or less concentrated in limited area within the effective range of the stations, the fact that a small fringe of listeners intermediate between stations received poor or even no transmission would be of small consequence.

It is at once evident, however, that in order that those listeners within the effective range of the station may properly receive, there must be a very close approximation to absolute synchronism between the different stations transmitting on the same wave length. Otherwise we would have an unsatisfactory receiving condition resulting from the production of beats. This would, of course, produce intense distortion of the signal at points where the received signal is relatively weak.

The purpose of the present invention, therefore, is to provide a system in which the wave lengths radiated from the several transmitting stations employing the same wave length will be maintained in absolute synchronism. It has been proposed to control the carrier frequencies at a number of radio stations employing different wave lengths by radiating a master control frequency to all stations, the carrier wave of each station being derived from the master control frequency. This method is not applicable to a system employing the same wave length at all stations for a number of reasons. In the first place, it is impractical to radiate a control frequency to various stations scattered over a large geographical area, because the control frequency would be too greatly attenuated before arriving at some of the stations. Furthermore, the phase relations of the control carrier frequency signal transmitted from a common point to all of the transmitting stations would not remain constant and could not be controlled as the factors affecting the phase change are of extra-terrestrial origin. It is therefore proposed in accordance with the present invention to maintain synchronism between the stations by generating a control frequency which is lower than the carrier wave of the transmitting station, then transmitting the wave so generated over wire lines to the various radio stations, amplifying it at points along the lines where necessary, and finally producing from the control frequency arriving at each transmitting station the carrier wave for the station by harmonic generation. The system involves essentially an arrangement of broadcast stations which are tied together by wires for the transmission of the program from a common point, the stations also being tied together by wires so that the carrier frequency or controlling frequency from which the carrier may be derived may be transmitted from a common point.

In the system above outlined, the program transmitted from each radio station would be delayed with respect to the original program by a time interval equal to that required to transmit the signal from the studio over the wire line leading to the station. Consequently a radio receiver located at some point approximately midway between two given radio stations would receive side band signals which would be out of phase with respect to each other by the difference in the time intervals required for the transmission of the signal over the wire line or lines to the radio stations. In other words, at a point between two radio stations, a side band corresponding to the signal would be received together with what might be described as an echo of the side band. These two side bands would be combined in the receiver to produce a composite wave which would not be a faithful reproduction of the signal wave, but a composite wave resulting from the combination of displaced parts of the same signal train. The invention therefore contemplates means to overcome this difficulty by insuring that the signal wave transmitted to the several radio stations will be delayed in transmission from the studio to each radio antenna by the same time interval.

Aside from the difficulty just stated, another important cause of distortion would exist in the system above described. Due to changes in the temperature of the conductors carrying the standard carrier control current, and due to changes in the leakage resistance between the conductors of the lines and between the line conductors and ground, with changing weather conditions, the phase of the standard carrier control current transmitted over the line will be changed. This change in phase is independent of the actual time lag due to the time of transmission of the control current from the source to the various radio stations. The control current being a sine wave, it would be immaterial how long it would take to transmit a given cycle from the source to the modulating point, provided the wave cycle arrived at the modulating point in the right phase. If, under a given set of conditions, the carrier control current arived at each modulating point in the proper phase relation, and the system were so arranged that the audio frequency signal itself arrived at each station simultaneously, the variation interference difficulties above outlined would not exist. As soon, however, as the phase of the arriving carrier control current is changed due to a variation in temperature or the like, the carrier control current will no longer arrive at each modulating point in the same phase relation. The result will be that (assuming the signal itself arrives at each transmitting station simultaneously) a carrier wave of the same frequency, but of different phase, will be modulated at each transmitting station. The carrier and the two modulation components thus radiated from two stations may be in such phase relation with respect to each other as to oppose each other at certain points between the two stations, so that in areas where the two waves arrive with substantially the same field strength, they would tend to cancel each other.

The changes in phase of the standard control frequency are very important from the standpoint of avoiding distortion due to the fact that the change in phase of the standard frequency is multiplied by the same factor that is used in multiplying or stepping up the standard frequency to the required carrier frequency at each transmitting station. Therefore, a small change in phase of the standard frequency on the wire line may become a very appreciable phase change at the carrier frequency. The effect of this phase change of the standard control current will result in shifting of the radio wave interference pattern at points receiving signals from at least two of the transmitting stations. It is therefore proposed, in accordance with the present invention, to provide a phase correcting arrangement whereby it will be possible to eliminate this shifting of the interference pattern in so far as this is due to changes in phase of the standard control frequency.

The invention may now be more fully understood from the description when read in connection with the accompanying drawing, Figures 1, 2 and 3 of which indicate in schematic form three different embodiments of the invention, Figs. 4 and 5 illustrate two forms of delay circuits which may be employed. Fig. 6 illustrates a phase correcting arrangement which may be employed in the systems of Figs. 1, 2 and 3. Fig. 7 illustrates a form of mechanism for operating the phase adjuster. Fig. 8 illustrates a modified form of phase adjusting apparatus, and Fig. 9 shows how the phase adjusting apparatus of Fig. 8 may be applied to a broadcasting system such as that illustrated in Fig. 1.

Referring to Fig. 1, three radio broadcasting stations A, B and C are shown linked together by wire lines, so that a common program may be transmitted from a studio S. At the studio S audio pick-up apparatus 10 is schematically indicated. This pick-up apparatus is well known in the art and may comprise a suitable microphone for receiving the music or other program to be transmitted, an amplifier for impressing it on the line with the desired amplitude, and, if necessary, monitoring equipment and attenuation equalizing devices such as are commonly used at broadcast stations in picking up and transmitting to a wire line program signals for broadcasting purposes. The output of the pick-up system 10 is connected to a wire line L for transmission to the several broadcasting stations A, B and C. A branch L_c from the line L extends to the radio transmitter T_c conventionally indicated at the station C. The line may also extend through a repeater station X at which is located a one-way repeater R_s for raising the level of the signal. The line may then extend from the repeater station to the radio transmitter T_a at the station A. A branch line L_b may extend from some point on the line L to the radio transmitter T_b at the station B. The branch line L_b, if necessary, may pass through a repeater station Y at which is located a repeater R_s' for raising the level of the signal transmitted to the station B.

The control or standard frequency source may, if desired, be located at the same station as the studio S, although so far as the principles of the invention are concerned it may be located at any other point. The source of the standard frequency is conventionally indicated in the drawing at F and may comprise any known means, such as a vacuum tube generator, for obtaining current of a known and standard frequency which may be, for example, 10,000 cycles per second. This frequency is applied to a line L′ which extends through the repeater station X and a one-way amplifier R_f thereat to station A. The branch L_c' extends from the line L′ to the station C. Likewise a branch L_b' extends from some point along the line L′ to the station B, the latter branch passing through the intermediate repeater station Y at which is located an amplifier R_f'.

Obviously, any number of broadcasting stations may be connected to a combined network of circuits similar to that above described, the one network transmitting the program signal and the other network transmitting the standard control frequency. Where the broadcasting station is located at a considerable distance from the source of the program signal and from the source of the control frequency, it will be necessary to include amplifiers such as those shown at X and Y in the wire circuits leading to such a station for the purpose of maintaining the transmission of the program and control frequency at levels suitable for obtaining high quality production, which means particularly freedom from noise and uniform transmission of the range of frequency in the program.

At each transmitting station some arrangement must be provided for translating the control frequency into the carrier frequency to be modulated. For example, at station A a frequency step-up arrangement is schematically indicated at HG_a. The frequency step-up arrangement may be of any type well known in the art, for example, the control frequency may be impressed upon a vacuum tube whose circuit is arranged to distort the wave and produce in its output harmonics of the control frequency. From these harmonics a desired harmonic which is to be the carrier wave may be selected and amplified. In the case illustrated, the sixty-first harmonic is selected and amplified and then impressed upon the radio transmitter to be modulated by the signal. As another illustrative example, if the assigned carrier frequency of the station was to be 635,000 cycles, a control frequency would be used which would be approximately fundamental for this frequency. For example, the control frequency might be 10,080 cycles, the sixty-third harmonic being selected to give a carrier wave of 635,040 cycles. Similar frequency step-up arrangements HG_b and HG_c are provided at stations B and C.

It will be seen that the above arrangement enables the carrier wave at all stations of the system to be fixed at the same wave length. Furthermore, the control frequency is transmitted at a wave length which will not interfere with receiving stations in the neighborhood of a given transmitter, for the reason that its transmission is confined to wire lines, thus avoiding radiation, and for the further reason that the control frequency is lower than the carrier wave. It will also be noted that the amplitude or level of the control frequency may be maintained at any desired value at any point by means of small one-way amplifiers included in the lines over which the control frequency is supplied.

The arrangement so far described, however, will not insure that the distortion due to difference in the time of transmission of the signal from the studio to the different transmitting stations, and the distortion due to change in phase of the standard control frequency will not occur. As has already been stated, if more time is required to transmit the signal from the studio to a given station, than is required to transmit the same signal from the studio to another station, side bands will be radiated to points intermediate the two stations, which will be delayed with respect to each other so that the side bands from the one station are in effect echoes of the side bands from the other station. When the side bands from the two stations are combined in a suitable radio receiver, the resultant signal will be a distorted combination resulting from combining in effect successive elements of the same signal wave at the same instant of time.

In order to overcome this difficulty, special delay circuits are provided. In Fig. 1, radio station B may be considered to be the most remote from the source of the program signal and the standard frequency signal. Therefore, it will be desirable to delay the transmission of the program signal from the studio to the radio stations A and C by time intervals, such that the side band signals from all of the radio stations are practically in time phase. This is accomplished by inserting a delay circuit D_a before the radio transmitter T_a in the line L at the radio station A, and by inserting a similar delay circuit D_c at a corresponding point in the line connection L_c at the station C. These delay circuits may be of the ordinary electrical network type, such as are commonly used for this purpose. An example of such a network is illustrated in Fig. 4 where it assumes the form of the so-called low-pass filter. A modified form of network of the so-called lattice type is illustrated in Fig. 5, and it will be understood that other types may also be employed. The amount of delay will depend upon the number of sections of the network, and consequently the delay circuits D_a and D_c will be provided with such a number of sections as will introduce the same time lag between the studio and the stations A and C, respectively, as is required for transmission between the studio and station B.

As has been previously pointed out, the standard control frequency must arrive at each of the radio stations in proper phase relation, and this phase relation must not vary if the waves radiated from any two stations are to maintain a fixed interference pattern. Due to various changes in physical conditions, and in particular changes in temperature, the phase at which the standard frequency arrives at the several transmitting stations changes from time to time, and any slight change in the phase of the standard frequency is multiplied as many times as the frequency itself is multiplied in stepping it up to the desired carrier frequency. It is therefore desirable to correct the phase of the standard frequency current applied to each of the transmitting stations, and particularly it is desirable to correct phase changes which are caused by variations in temperature of the wire line, and by variations of its leakage resistance.

For this purpose, a phase corrector P_a is inserted in the line L′ at the station A in front of the frequency step-up device HG_a, and a similar phase corrector P_b is inserted in the line L_b' at the station B ahead of the frequency set-up device HG_b. No phase corrector need be inserted at the station C, for it is assumed that this station is located at the same point as the studio S, so that no substantial phase change occurs in the transmission of the standard frequency from the studio S over the conductors L_c to the radio transmitter at C.

The phase correcting device to be employed at stations A and B may be of the form illustrated in Fig. 6. In this figure, the standard frequency is applied to a wire line through a transformer 25, and the wire line is terminated at a radio transmitting station in a phase splitting circuit comprising a resistance R_1 and a capacity C_3. Phase splitting coils L_1 and L_2 are arranged at right angles to each other, and have their common terminals connected to the junction point between the resistance R_1 and the condenser C_3, while their opposite terminals are connected to the other terminals of the resistance R_1 and condenser C_3, respectively. A third coil L_3 serves as a pick-up coil and is arranged to be adjusted in the rotary field produced by the phase splitting coils L_1 and L_2, so that the phase of the wave transmitted through the coil L_3 to the frequency step-up circuit will depend upon the adjustment of the coil L_3 with respect to the phase splitting coils.

In order to control the adjustment of the coil L_3, the wire line is arranged to form one arm of a Wheatstone bridge, of which resistances R_2, R_3 and R_4 comprise the other three arms. As we are concerned mainly with the resistance of the line in forming the bridge combination, it is necessary that direct current by-pass connections be provided at all repeater points in the line, so that a complete metallic circuit extends from the point where the standard frequency is applied to the line, to the termination of the line where it is connected to the Wheatstone bridge. Such direct current connections are common practice in the repeater art for the purpose of by-passing composite telegraph circuits around repeaters, and for that reason are not illustrated here. In the terminal connections from the line to the bridge, choke coils 35 may be provided to prevent the A. C. currents from entering the bridge, and likewise condensers, such as C_1 and C_2 may be provided in the connections leading to the split phase coils for preventing the direct current from entering this part of the circuit.

The Wheatstone bridge is arranged to automatically maintain a balance with the varying resistance of the wire line. This is accomplished by means of the sliding contact of the resistance R_2 which is controlled by a suitable motor 26. The direction of rotation of the motor is controlled by a reversing relay 36 connected across the balanced arms of the bridge, as shown, the relay being actuated by current received from the battery B_1 of the bridge whenever the bridge is unbalanced. The motor 26 is also mechanically related to the adjustable coil L_3 so that the coil may be adjusted with respect to the split phase coils L_1 and L_2 by an amount bearing some desired relation to the adjustment of the sliding contact necessary to balance the bridge. The relative amount of movement of the sliding contact and the pick-up coil may be suited to the phase changes occurring on the line by properly designing the mechanical gearing or other arrangement for interconnecting the motor shaft with the slidable contact and the pick-up coil. The simplest arrangement, however, is to have the motor drive two shafts 27 and 28, as shown in Fig. 7, the shaft 27 being threaded at its end to carry the sliding contact 29, so that it is dragged back and forth along the resistance R_2 as the motor rotates. The shaft 28, on the other hand, is provided with a worm gear 30 to mesh with the worm gear 31 which rotates the shaft 32 carrying the adjustable coil 33. By properly proportioning the successive elements of the resistance R_2 over which the sliding contact 29 moves from point to point, the characteristics of the variation of the resistance R_2 and the adjustment of the coil L_3 in the field of the coils L_2 may be arranged to conform to the law of variation between the temperature and phase shift of the standard signal on the wire line.

A modified arrangement is illustrated in Fig. 2 which enables the same network which supplies the program to several transmitting stations to be employed for supplying the control frequency. Here the audio pick-up apparatus 10 and the standard frequency source F are connected to the line L. At the repeater station X the line L is branched through a low-pass filter F_s and a high-pass filter F_f, so that the amplifier R_s will serve to amplify the program signal to be broadcast, and the amplifier R_f will amplify the control frequency of 10,000 cycles selected by the high-pass filter. Similarly, at the transmitting station a low-pass filter LP_a selects the program signal to impress it on the radio transmitter, while the high-pass filter HP_a selects the control frequency which is impressed upon the frequency step-up device HG_a. The desired harmonic is selected and amplified as described in Fig. 1 and impressed upon the radio transmitter to be modulated by the signal. The branch line L_b carrying both the program signal and the control frequency leads to the station B, where radio transmitting apparatus is schematically indicated, the apparatus being identical with that shown at the station A. At a repeater point Y the program and the control frequency are selected into branches for amplification by apparatus similar to that shown at X. A branch L_c leads from the line L to the apparatus at station C, the apparatus being identical in character to that illustrated at station A.

The arrangement shown in Fig. 2, of course, has the advantage that the same line system may be employed both for the program signal and for the control frequency. The disadvantage of the arrangement is that, in general, the control frequency will have to be spaced above the program frequency a sufficient amount to permit a proper selection. It may therefore readily happen that the control frequency will be too high to transmit over a transmission line without undue attenuation. Where such is the case, a system of the type shown in Fig. 1 will be advantageous, for there the control frequency may be made as low as desired. The system of Fig. 1 also has the advantage that it is unnecessary to supply selective filters at the repeater points and at the transmitting stations.

In the arrangement of Fig. 2, a delay circuit D_a may be inserted between the low-pass filter LP_a and the radio transmitter T_a at station A, and likewise a delay circuit D_c may be inserted between the radio transmitter T_c and the low-pass filter LP_c at station C. These delay circuits should be so designed as to introduce the same delay between the studio and stations A and C. respectively, as is required for transmission of the audio signal from the studio to station B. Likewise, automatic phase adjusting devices, such as that illustrated in Fig. 6 may be applied at stations A and B. The automatic phase changer P_a at station A is inserted between the high-pass filter HP_a and the frequency step-up device HG_a, and a similar phase adjuster will be provided at the corresponding point in the apparatus at station B (not illustrated in detail).

Fig. 3 illustrates a system in which the program signal is transmitted over the line at an intermediate carrier frequency. At the radio station the intermediate carrier frequency is modulated with another frequency derived from the intermediate carrier frequency to obtain the modulated radio carrier frequency for radio transmission.

At station S a modulator M is provided which may be of any well known type, such, for example, as a vacuum tube modulator. The program signal from the pick-up apparatus 10 and the control frequency from the source F are impressed upon the modulator so that the control frequency is modulated by the program signal. On the output side of the modulator a band-pass filter BP is provided which will select both side bands and the intermediate carrier frequency of 10,000 cycles. The side bands and the intermediate carrier are then impressed upon the line L. A branch L_c extends from the line L to the transmitting station C at which two selecting circuits are provided.

The one selective circuit BP_c is a band-pass filter adapted to pass the same band as the filter BP at the studio S. The other selective circuit may be, for example, a sharply tuned circuit which selects the carrier frequency of 10,000 cycles. The selected intermediate carrier frequency of 10,000 cycles is impressed upon a frequency step-up device HG_c which may be of the type described in connection with Fig. 1. In this case, where the final carrier is to be 610,000 cycles, the sixtieth harmonic of 600,000 cycles is selected and amplified and then impressed upon the modulator M_c. This frequency is modulated by the two side bands and the intermediate carrier passed through the filter PB_c. This produces in the output circuit of the modulator M_c sum and difference frequencies which correspond to a carrier frequency of 610,000 cycles with its corresponding upper and lower side bands. In the output side of the modulator there would also appear a band of frequencies corresponding to a carrier of 590,000 cycles with its corresponding side bands, but these frequencies are rejected by the filter PB_c. Consequently the carrier frequency of 610,000 cycles with its corresponding side bands is transmitted to the radio transmitter T_c, which in this instance, may comprise suitable amplifying and transmitting equipment.

The line L may extend through a repeater station X including a one-way amplifying equipment schematically indicated. This amplifying equipment may be of the usual vacuum type arranged in a manner well understood in the art to amplify the entire band including the intermediate carrier and both side bands. A branch L_b from the line L may extend through a similar repeater station Y to a transmitting station B. The transmitting station A associated with the line L and the transmitting station B associated with the branch line L_b each comprise apparatus similar to that illustrated in connection with the station C.

The arrangement illustrated in Fig. 3 may, of course, be provided with delay circuits D_a and D_b at stations A and C, respectively, as indicated, to ensure that the time required to transmit the signal from the studio to the modulator at each of the stations A, B and C will be the same. Likewise, phase correctors P_a and P_b of the type illustrated in Fig. 6 may be inserted at stations A and B, respectively, between the selecting circuit and the frequency step-up device to compensate for changes in the phase of the frequency control. No phase adjuster is necessary at the station C because of its proximity to the studio.

The phase adjusting arrangement illustrated in Fig. 6 is intended to be used at the distant end of the line from the point at which the standard frequency is applied. A modified phase adjusting arrangement is illustrated in Fig. 8, so arranged that it may be applied to the incoming end of the line, that is, to the end of the line at which the standard frequency is applied. In this case, the phase splitting elements R_1' and C_3' are bridged across the end of the circuit at which the standard frequency is applied, and the phase splitting coils L_1' and L_2' are connected to the resistance R_1' and condenser C_3' in a manner similar to that illustrated in Fig. 6. The adjustable coil L_3' is movable in the rotary field of the phase splitting coils and serves to inductively connect the standard frequency source or the terminals at which the standard frequency is applied to the incoming end of the line. At the outgoing end of the line where it is associated with the frequency step-up apparatus of the radio station, it is terminated in a conductive path 46 shunted across the line, a condenser 47 being provided to prevent the direct current from flowing into the equipment at the radio station. The part of the line extending from the phase splitting apparatus to the distant radio station serves as one arm of the Wheatstone bridge, the line being connected to the arm terminals through the choke coil 35′, as before. The automatic adjustment of the bridge and the coil L_3 is controlled by a motor 26′ through mechanisms and circuits similar to those described in connection with Fig. 6.

Obviously, with an arrangement such as that shown in Fig. 8, the phase adjuster must be located at the input end of any branch of the line leading to a particular radio station, and it must operate to make phase adjustments for that particular branch. The portion of the line intervening between the standard frequency source and the branch point must, of course, be compensated for by a phase correcting arrangement applied to that part of the line near the source itself.

In order to understand how the phase correcting arrangement of Fig. 8 may be applied to circuits of the type shown in Figs. 1, 2 and 3, attention is called to the circuit shown in Fig. 9 which illustrates the phase correcting arrangement of Fig. 8 as applied to the type of circuit illustrated in Fig. 1. Here it will be noted that the controlling frequency applied to the station C need not be compensated, as the station C is in close proximity to the studio at which the standard frequency source is located. The line L′ extending from the standard frequency source to the station A is compensated by means of a phase corrector P_a' located in the line adjacent the station S. Just outside of the station A the line is terminated by a condenser inductance combination corresponding to elements 46 and 47 of Fig. 8, so that the phase corrector P_a' serves to automatically make adjustments for variations in the line between the studio and the point at which the termination occurs.

The line branch L_b' leading to the station B is bridged across the termination of the line L′ at station A and must be separately compensated for phase changes. Accordingly, a phase corrector P_b' of the type described in Fig. 8 is connected in the line at a point which branches from the line L′ at station A.

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 appended claims.

What is claimed is:

1. In a broadcasting system comprising a plurality of transmitting stations located in different areas, a program source, a wire network for connecting said program source to each of said transmitting stations, a control frequency source, means to transmit the control frequency from said source over wire conductors to each of the transmitting stations, means at each transmitting station to produce a carrier frequency under the control of said control frequency, means to maintain a constant phase relation between the carrier frequency currents at each transmitting station, and means at each transmitting station to modulate the carrier frequency in accordance with the program from said program source.

2. In a broadcasting system comprising a plurality of transmitting stations located in different areas, a program source, a wire network for connecting said program source to each of said transmitting stations, a control frequency source, means to transmit the control frequency from said source over wire conductors to each of said transmitting stations, means at each transmitting station to produce under the control of said control frequency the same carrier frequency, means to maintain a constant phase relation between the carrier frequency currents at each transmitting station, and means to modulate the carrier frequency thus produced at each station in accordance with the program signal transmitted to said station.

3. In a broadcasting system, a plurality of transmitting stations located in different areas, a program source, a wire network connecting said program source to each of said transmitting stations, a control frequency source, means to transmit the control frequency from said source over wire conductors to each of said transmitting stations, means at each transmitting station to produce harmonics of the control frequency, means to select the same harmonic for the carrier frequency at each transmitting station, means to maintain a constant phase relation between the carrier frequency currents at each transmitting station and means at each transmitting station to modulate the selected harmonic in accordance with the program signals transmitted to said stations.

4. In a broadcasting system, a plurality of radio transmitters located in different areas, a program source, wire lines connecting said program source to each of said program transmitters, a control frequency source, wire lines connecting said control frequency source to each of said program transmitters, means at each of said transmitters for producing the same carrier frequency under the control of said control frequency, means to maintain a constant phase relation between the carrier frequency currents at each transmitting station, and means at each transmitter for modulating the carrier frequency in accordance with said program signal.

5. In a broadcasting system, a plurality of radio transmitters located in different areas, a program source, wire lines connecting said program source to each of said program transmitters, a control frequency source, wire lines connecting said control frequency source to each of said program transmitters, means at each transmitter for producing harmonics of said control frequency source, means to select at each transmitter the same harmonic for use as a carrier frequency, means to maintain a constant phase relation between the carrier frequency currents at each transmitting station, and means at each transmitter for modulating the selected harmonic in accordance with the program signal.

6. In a broadcasting system comprising a plurality of transmitting stations located in different areas, a program source, a wire network for connecting said program source to each of said transmitting stations, means in said network for equalizing the time of transmission of the signal from the program source to each of said transmitting stations, a control frequency source, means to transmit the control frequency of said source over wire conductors to each of the transmitting stations, means at each transmitting station to produce a carrier frequency under the control of said control frequency, means to maintain a constant phase relation between the carrier frequency currents at each transmitting station, and means at each transmitting station to modulate the carrier frequency in accordance with the program from said program source.

7. In a broadcasting system comprising a plurality of transmitting stations located in different areas, a program source, a wire network for connecting said program source to each of said transmitting stations, delay

circuits interposed in said wire network to equalize the time required to transmit a signal from the program source to each of said transmitting stations, a control frequency source, means to transmit the control frequency of said source over wire conductors to each of the transmitting stations, means at each transmitting station to produce a carrier frequency under the control of said control frequency, means to maintain a constant phase relation between the carrier frequency currents at each transmitting station, and means at each transmitting station to modulate the carrier frequency in accordance with the program from said program source.

8. In a broadcasting system comprising a plurality of transmitting stations located in different areas, a program source, a wire network for connecting said program source to each transmitting station, a control frequency source, means to transmit the control frequency from said source over wire conductors to each of the transmitting stations, phase adjusting means associated with said wire conductors for maintaining the same phase relation between the control frequency currents arriving at the several transmitting stations under varying physical conditions, means at each transmitting station to produce a carrier frequency under the control of said control frequency, and means at each transmitting station to modulate the carrier frequency in accordance with the program from said program source.

9. In a broadcasting system comprising a plurality of transmitting stations located in different areas, a program source, a wire network for connecting said program source to each of said transmitting stations, a control frequency source, means to transmit the control frequency from said source over wire conductors to each of the transmitting stations, means in said wire conductors automatically responsive to changes in the resistance thereof to compensate for changes in the phase of the control frequency currents arriving at the several transmitting stations, means at each transmitting station to produce a carrier frequency under the control of said control frequency, and means at each transmitting station to modulate the carrier frequency in accordance with the program from said program source.

10. In a broadcasting system comprising a plurality of transmitting stations located in different areas, a program source, a wire network for connecting said program source to each of said transmitting stations, delay circuits in said wire network for equalizing the time required for transmission of a program signal from said program source to each of said transmitting stations, a control frequency source, means to transmit the control frequency from said source over wire conductors to each of the transmitting stations, phase adjusters in said wire conductors, said phase conductors being automatically responsive to changes in the electrical characteristics of said conductors for automatically maintaining the phase relation of the control frequency currents arriving at the several transmitting stations, means at each transmitting station to produce a carrier frequency under the control of said control frequency, and means at each transmitting station to modulate the carrier frequency in accordance with the program from said program source.

11. A phase compensating arrangement comprising a transmission path, means to apply alternating currents to said path, means to automatically maintain the phase of alternating currents arriving at the distant end of said path, said means comprising a bridge arrangement, of which the transmission path comprises one arm, mechanism to automatically balance the bridge, a phase adjusting element associated with said path, and means controlled by said automatic mechanism for adjusting said phase adjusting element.

12. A phase compensating arrangement comprising a transmission path, means to apply alternating currents to said path, means to automatically maintain the phase of alternating currents arriving at the distant end of said path, said means comprising a bridge of which said path constitutes one arm, mechanism for maintaining the bridge automatically balanced, a phase adjusting device associated with said path, said phase adjusting device comprising split phase coils for producing a rotating field, a secondary coil adjustable in said field, and means to adjust said secondary coil under the control of said mechanism for automatically balancing the bridge.

13. In a broadcasting system comprising a plurality of transmitting stations located in different areas, a control frequency source, means to transmit the control frequency from said source over wire conductors to each of the transmitting stations, phase adjusting means associated with said wire conductors for maintaining the same phase relation between the control frequency currents arriving at the several transmitting stations under varying physical conditions, means at each transmitting station to produce a carrier frequency under the control of said control frequency, and means at each station to modulate the carrier frequency in accordance with signals.

14. In a broadcasting system comprising a plurality of transmitting stations located in different areas, a control frequency source, means to transmit the control frequency from said source over wire conductors to each of the transmitting stations, means in

said wire conductors automatically responsive to changes in the resistance thereof to compensate for changes in the phase of the control frequency currents arriving at the several transmitting stations, means at each transmitting station to produce a carrier frequency under the control of said control frequency, and means at each transmitting station to modulate the carrier frequency in accordance with signals.

In testimony whereof, we have signed our names to this specification this 24th day of August, 1926.

LLOYD ESPENSCHIED.
RALPH BOWN.
DE LOSS K. MARTIN.