

March 10, 1936.

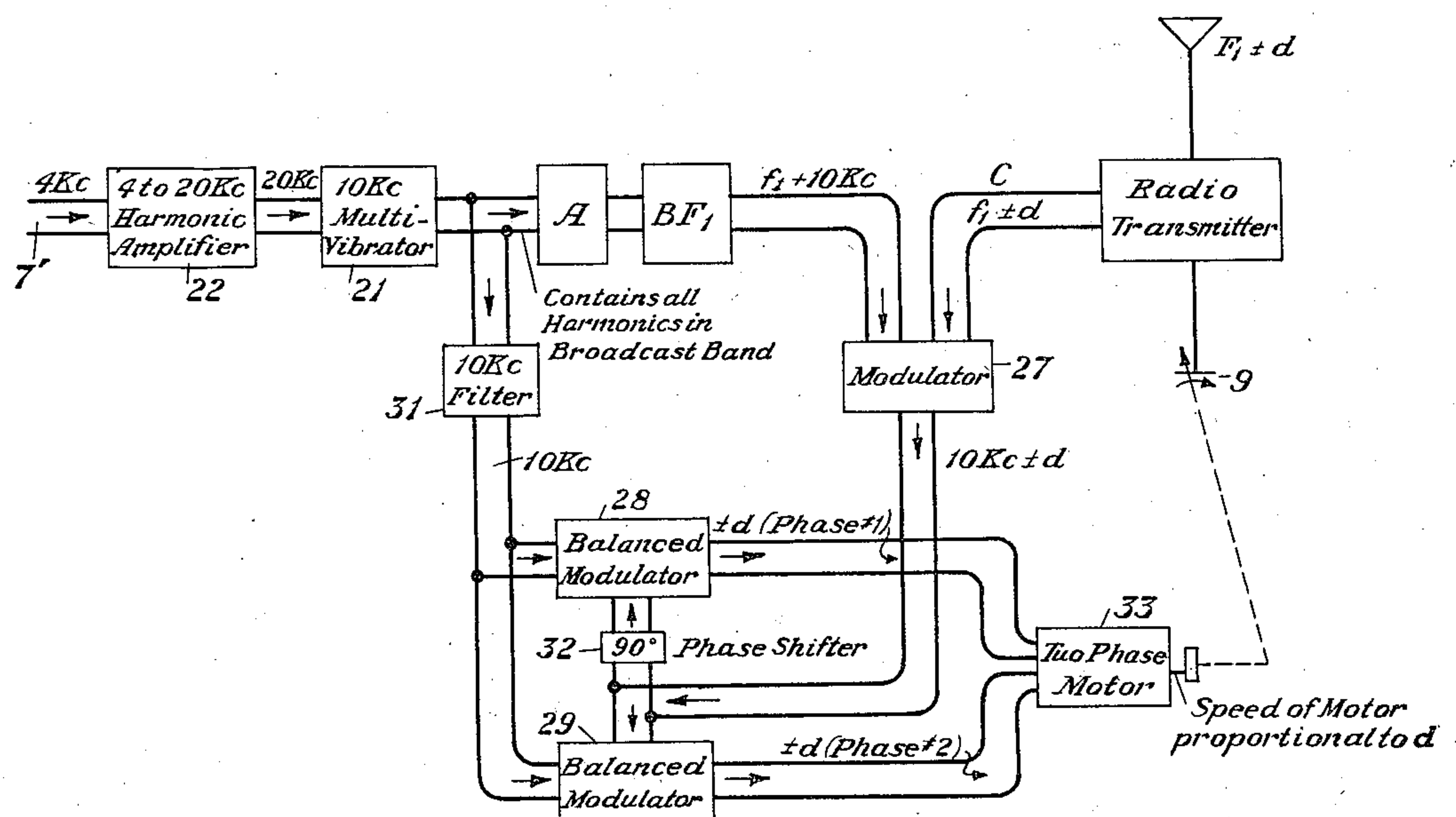
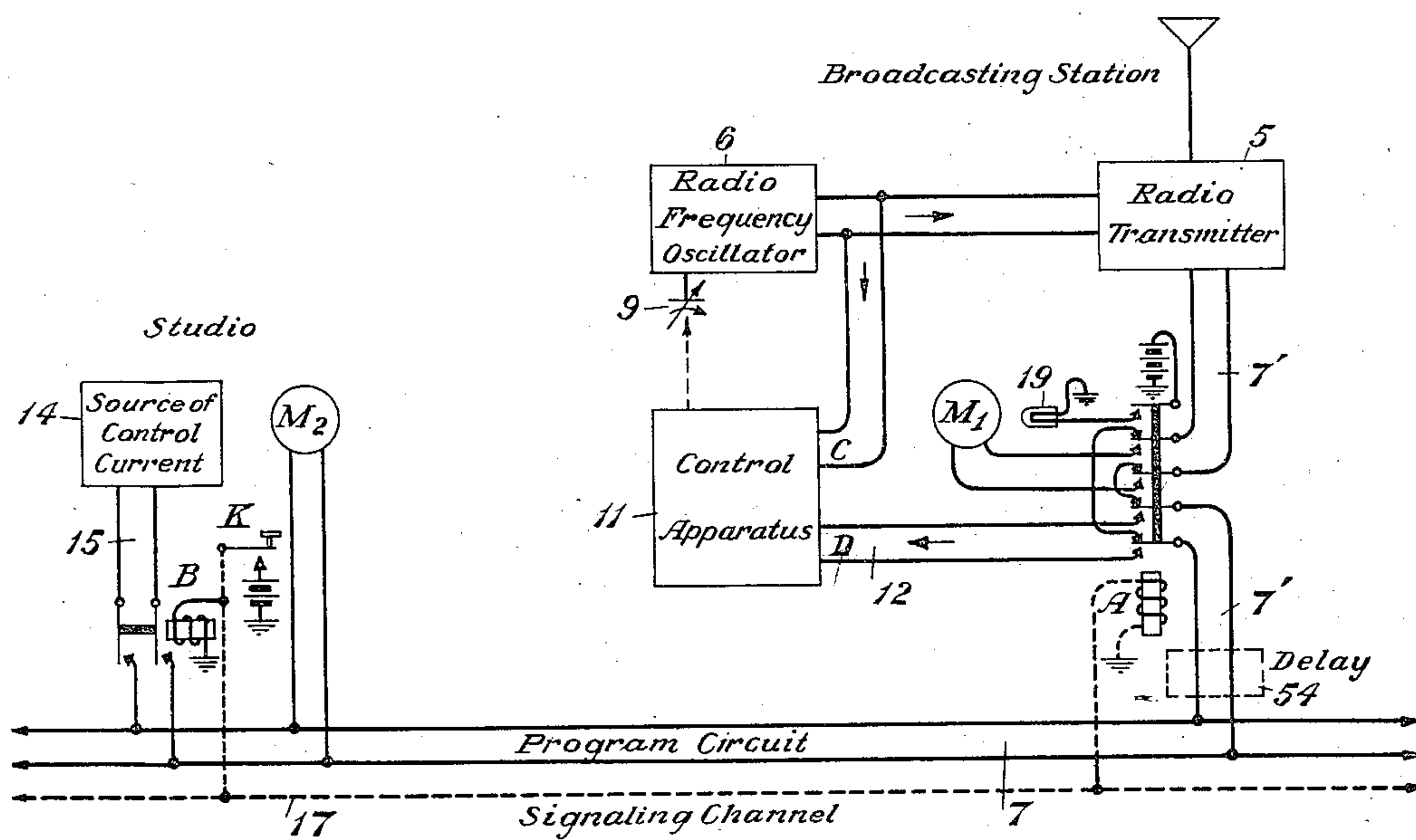
D. K. GANNETT

2,033,237

FREQUENCY CONTROL SYSTEM

Filed Aug. 15, 1934

2 Sheets-Sheet 1



INVENTOR

D. K. Garnett

BY

ATTORNEY

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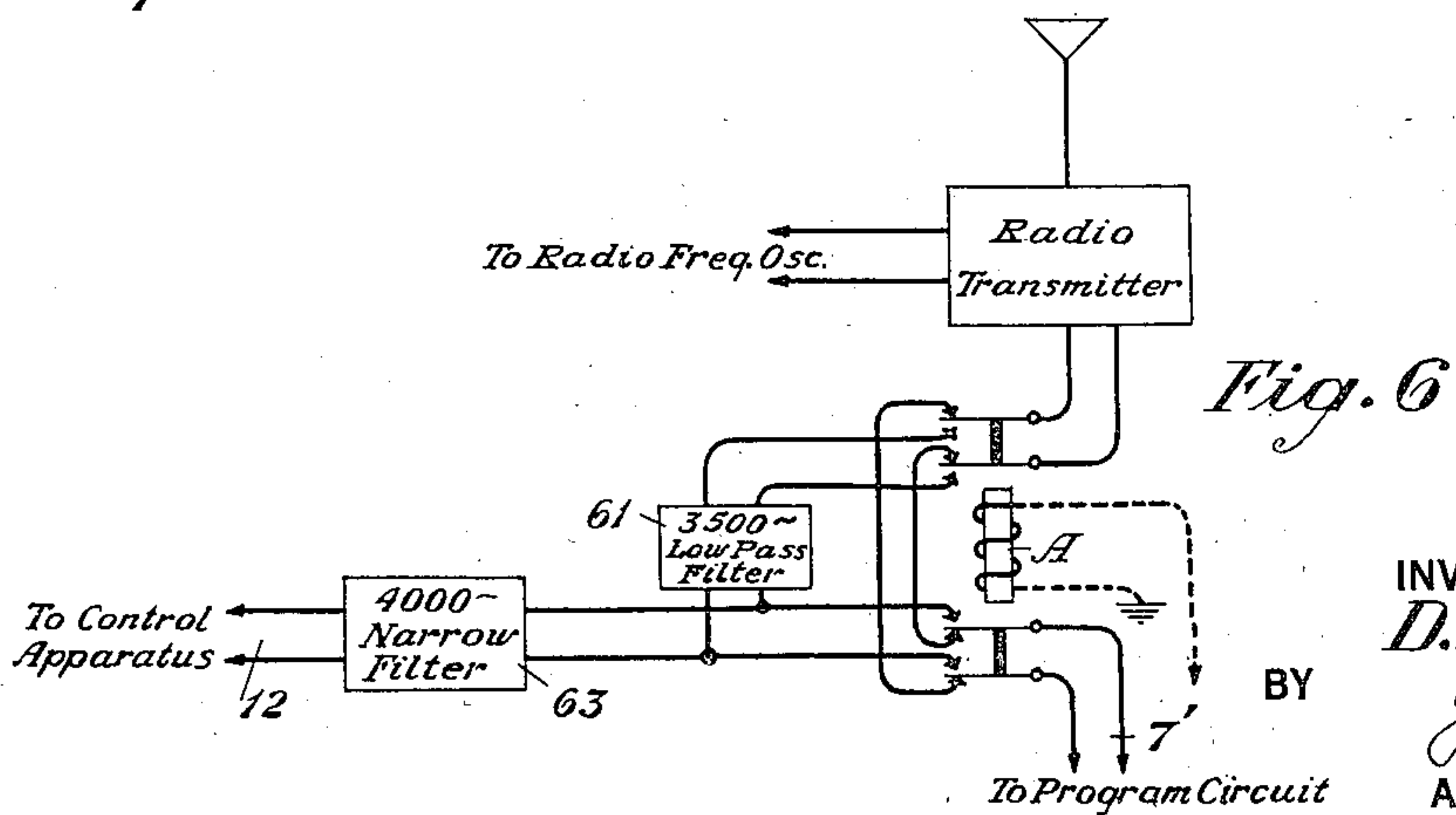
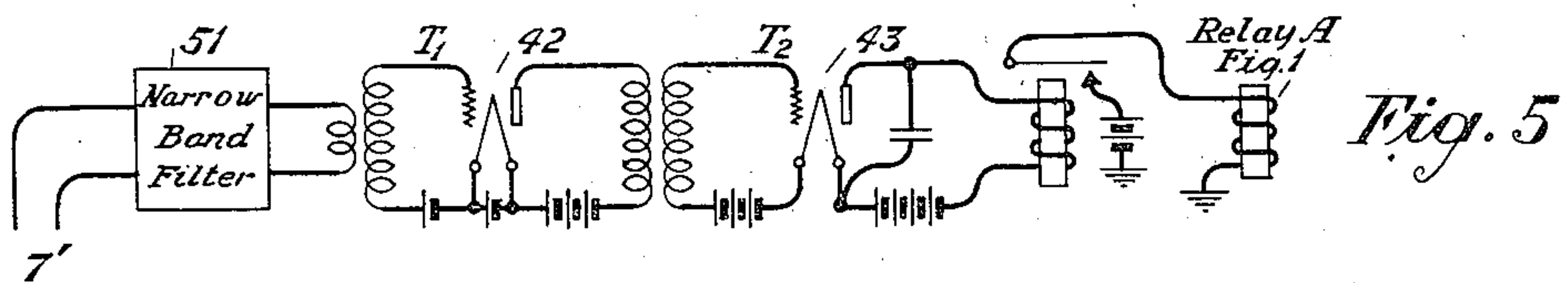
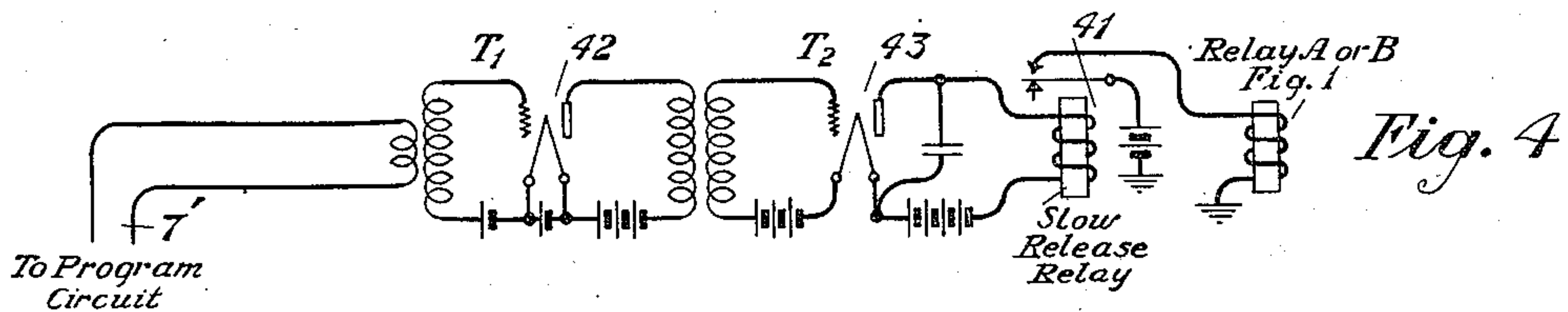
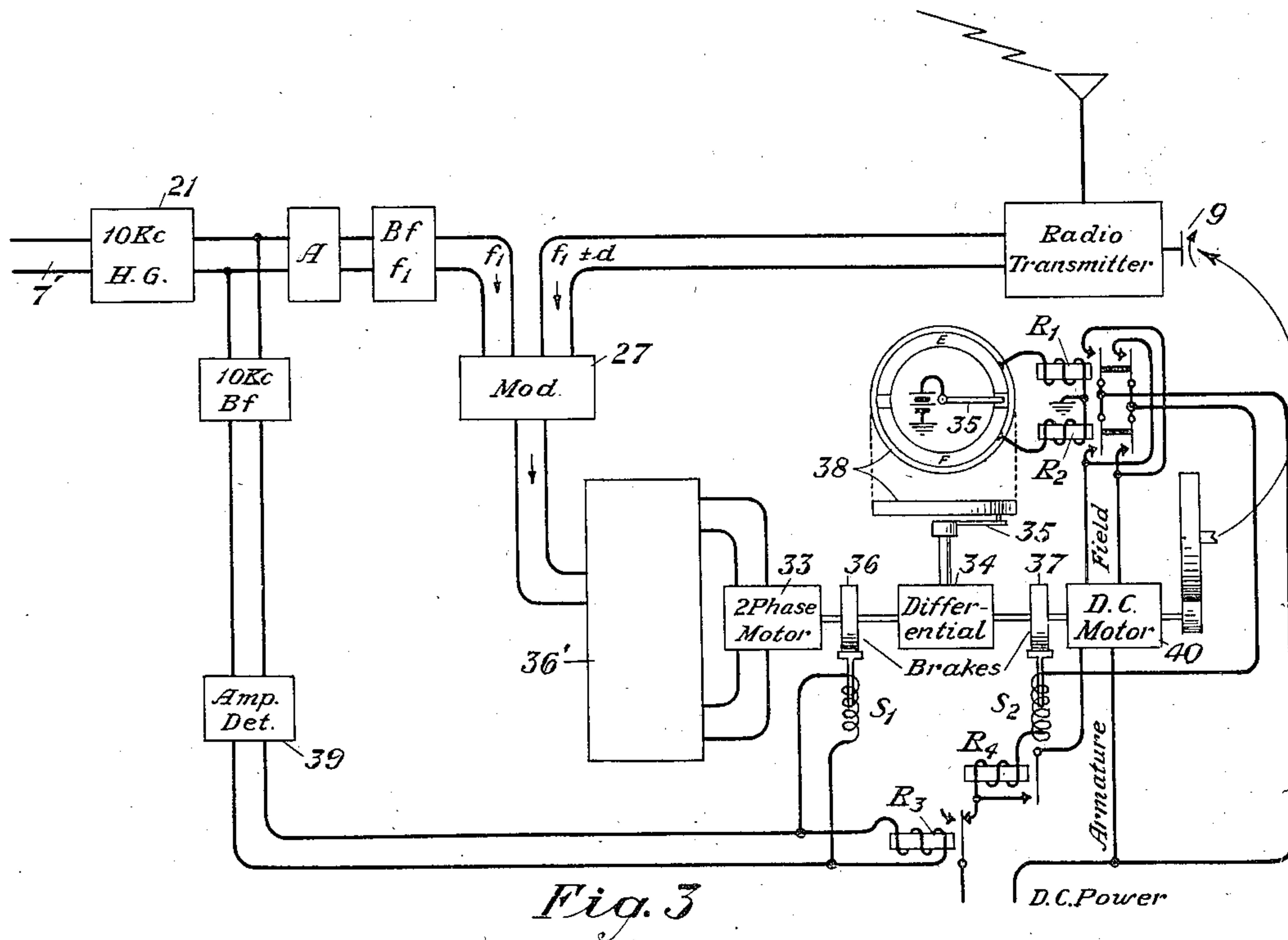
D. K. GANNETT

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2 Sheets-Sheet 2



INVENTOR
D.K. Gannett
BY *g e f o l e*
ATTORNEY

UNITED STATES PATENT OFFICE

2,033,237

FREQUENCY CONTROL SYSTEM

Danforth K. Gannett, Jackson Heights, N. Y.,
 assignor to American Telephone and Telegraph
 Company, a corporation of New York

Application August 15, 1934, Serial No. 739,989

13 Claims. (Cl. 250—2)

This invention relates to the synchronizing of a plurality of local sources of current by means of a master source, the waves from which may be transmitted to the various stations to be synchronized. More particularly, the invention relates to the transmittal of standard or standardizing frequencies over a system of lines going to a plurality of radio stations, which stations it is desired to operate on a common frequency, all in suitable phase relationship to each other.

One method by which this has heretofore been done is by sending out such a control frequency continuously from a master station, over a line, to the various stations to be operated in synchronism, as illustrated in patent to Marrison No. 1,931,873, October 24, 1933. In such systems the program to be broadcast will usually be the same for all the stations to be synchronized, and such program may come from the master station or from some other place, but the standard frequency in the case of the patent referred to is sent over a different channel, which is usually a different physical line.

In this invention I propose, and this constitutes one purpose of my invention, to avoid the necessity of a separate synchronizing circuit by using the program circuits for the occasional transmission of the necessary control currents to the broadcasting stations and to this end I send out such standard or standardizing frequencies over the same channel, or at least the same physical line as is used for the programs, and do so during the short intermissions between the programs or portions of programs or during relatively unimportant parts of the program.

Another purpose of the invention is to devise a control system which will operate satisfactorily to control the local source at any station even though the controlling frequency be impressed for short intervals of time separated by relatively long intervals.

Still other purposes of the invention will be apparent from the disclosure hereinafter.

The invention will be better understood by reference to the following specification and the accompanying drawings, in which Figure 1 shows one modification of a system embodying my invention; Fig. 2 shows one modification of the control apparatus of Fig. 1; Fig. 3 shows another modification of such control apparatus; and Figs. 4, 5, and 6 show modifications of the arrangement by which the control apparatus of Fig. 1 is brought into action during the necessary short intervals of time.

Referring more specifically to Fig. 1, there is

shown a radio transmitter system 5 supplied with radio frequency oscillations from generator 6, and also with program coming from some remote point over a program circuit 7. The oscillation generator 6 is a substantially independent oscillator the frequency of which can be altered slightly by manipulation of the condenser 9. In the event that this oscillation generator drifts somewhat from its normal frequency, it is returned to that normal frequency through the operation of control apparatus 11, which in turn receives control frequency over the circuit 12.

The details of the control apparatus 11 are shown in Fig. 2 and will be described below. The manner in which control frequency reaches the apparatus 11 is as follows: A source of control current is shown at 14, this source being connected to the program circuit through connections 15, which connections are normally open at the contacts of relay B. Operation of a key K closes the circuit 15 to the program circuit 7 and at the same time closes circuit through relay A over a signaling channel 17, which may be of a relatively inexpensive type, such as a telegraph channel. The operation of relays B and A connects the control frequency source to the program circuit and at the same time disconnects the program circuit from the radio transmitter, but connects it to the control apparatus 11 over the circuit 12. Coincidentally the relay A connects a microphone M₁ to the radio transmitter, whereupon the announcer at the station takes control. Also, a signal 19 may be operated to indicate to the announcer that the key K has been operated.

This operation of the key K would normally be made during the interval of some 15 or 30 seconds which usually occurs between two programs, although it might be done at any other time which the program permits.

The control apparatus 11 may be that shown in Fig. 2, which is substantially the arrangement disclosed in the patent to Marrison referred to above. It effectively compares the frequencies at the terminals C and D, and if these do not bear the desired ratio to each other it operates a two-phase motor or other suitable mechanism which adjusts the small condenser 9 associated with the oscillation generator 6 so as to correct the frequency of that generator. In the circuit there is shown a multi-vibrator 21 which may be operated for a fundamental frequency of 10 kilocycles, the output being rich in harmonics thereof. This fundamental frequency may be obtained directly by transmission from the control source or may be derived in any suitable manner from some

other control frequency. Thus in the figure, for purposes of illustration, I have shown an incoming control frequency of 4 kilocycles going to a harmonic amplifier yielding, among other things, a frequency of 20 kilocycles. The 20 kilocycles, in turn, are used to operate the multi-vibrator whose fundamental frequency is 10 kilocycles, all in a manner well understood in the art. A part of the output of the multi-vibrator is applied to an amplifier A and a band filter BF₁ which passes a frequency $f_1 + 10$ kc. where f_1 is the normal frequency of the transmitting station. This harmonic and the station frequency $f_1 \pm d$ at terminal C are applied to a modulator 27 whose output, therefore, consists of the beat frequency between these two input currents. This beat frequency is 10 kc. plus whatever error exists in the station frequency, and is transmitted to one of the inputs of each of two balanced modulators 28 and 29. The other input circuits of these modulators are fed directly from the 10 kc. vibrator through the filter 31. The outputs of these two balanced modulators, therefore, have a frequency equal to the error in the station frequency, and on account of a 90° phase shifter 32, which is shown in series with one of the inputs to one of the modulators, these two currents are 90° out of phase. This two-phase current from the modulators is now applied to a two-phase motor 33 whose speed and direction of rotation are proportional to the error in the station frequency. The motor is geared to the condenser 9 associated with the station oscillator in such a manner that its rotation tends to correct the error.

In the above figure special reference has been made to a signal control frequency of 4,000 cycles. This particular value is one used in practice for the reason that it lies just above the band ordinarily used for normal telephone transmission and also just below the bands used in carrier current signaling. Thus it may be "squeezed in", as it were, between two signal channels on some physical line. On the other hand, all radio frequency carrier frequencies are assigned as multiples of 10 kilocycles, and it is desirable therefore to transform the 4,000 kc. to 10 kc. and this accounts for the particular arrangement shown in Fig. 2. It is to be understood, however, that the invention is not limited to the use of these frequencies.

With the arrangement described in Fig. 2 it is apparent that the correction is applied in a logarithmic manner, the closer the adjustment to the correct frequency the slower being the speed of the motor. Unless, therefore, the speed of correction is great, the amount of correction obtained in a short interval of 10 or 15 seconds may not be sufficient to restore the frequency the desired amount. An arrangement by which this difficulty may be overcome is shown in Fig. 3. In this figure there is present the 10 kc. harmonic generator 21, part of the output of which passes through the amplifier A and band pass filter which, in this case, would again pass the n th harmonic of the multi-vibrator, which harmonic could well have the frequency $f_1 + 10$ kc., where f_1 is the frequency at which the transmitting station is intended to operate. This frequency and a portion of the output from the station oscillator of frequency $f_1 \pm d$ are transmitted to the modulator 27. The output of 27 would now be impressed on a system similar to the double balanced modulator and phase shifter of Fig. 2, and shown at 36' of Fig. 3 to control a two-phase motor, or the output of 27 may be applied to any other

system represented by 36' by which the motion of a motor could be controlled in accordance with the value of $\pm d$.

Thus far the system as described is the substantial equivalent of the corresponding portion of Fig. 2 and is a modified form of circuit which may replace the corresponding part of Fig. 2, or in turn may be replaced by the corresponding portion of Fig. 2. From this point on, however, the system differs from that of Fig. 2 in that the two-phase motor makes no direct correction in the station frequency but is connected through differential gears 34 to a contact arm 35 which normally rests on the insulating space between two segments E and F mounted on a disc 38.

On receipt of a spurt of synchronizing frequency lasting a definite time interval, say 10 seconds, the contact arm 35 will be displaced from its normal position over segment E or F by an amount depending upon the error in the station frequency, the direction of displacement being determined by whether the station frequency is high or low. Upon termination of the impulse the motor is stopped by the brake 36 actuated by the release of the solenoid S₁, which in turn is operated by current from the amplifier-detector 39 drawing power from the control frequency channel. At the same time the relay R₃ is released, applying power to the auxiliary D. C. motor 40 which is also connected to the contact arm through the differential. The release of the relay R₃ at the same time causes the operation of solenoid S₂ to release the brake 37, thus permitting rotation of the motor 40. This motor revolves in a direction determined by whether the contact arm 35 is resting on segment E or F, and continues to revolve until the contact arm has returned to its normal position between the two segments. This latter control is obtained through the relays R₁ and R₂ operating to send the current through the field windings of the motor in the one direction or the other in a manner which is clear from the drawings.

The D. C. motor 40 in addition to driving the contact arm is also geared to the condenser 9 associated with the station oscillator so that a correction in the frequency is made, the amount of correction being determined by the displacement which was made in the position of the contact arm by the two-phase motor in the given time interval during which the synchronizing impulse was received.

In Fig. 4 there is shown a modification of the arrangement by which relays A and B of Fig. 1 are operated. In this figure a voice-operated switching arrangement is applied. As long as there is a program on the circuit a slow-release relay 41 connected to the output of the amplifier-detector 42—43, is kept operated. In the case of any brief cessation in the program this slow-release relay is released, operating relay A to change the connections in the manner heretofore described in connection with Fig. 1. At the same time a similar circuit is applied to the program circuit at the source of control current to operate the relay B, and thus it is seen that on the operation of both relays A and B the synchronizing current is connected to control the equipment at the broadcasting station. In order to radiate no sound from the synchronizing current it is desirable to design the voice-operated arrangement at B to have a slower releasing time than the voice-operated arrangement at the relay A.

A still further modification is shown in Fig. 5.

This consists of an amplifier-detector arrangement similar to that shown in Fig. 4 except that it is designed to be operated by the synchronizing current rather than the program, and the arrangement need be applied at relay A only. At the time it is desired to connect the station frequencies the control current is applied to the program circuit at B. A narrow band filter 51 at the relay station A selects the control frequency such, for example, as a 4,000-cycle current, and applies this to the amplifier-detector, operating the relay connected to the output of the detector 43, which in turn operates relay A at the broadcasting station. An adjustment of the oscillation generator circuit then proceeds. It is apparent in this case that a momentary spurt of 4,000 cycles to the radio transmitter would result unless a delay circuit were included between the program circuit and the relay contacts to give time for the relays to operate. Such a delay device is shown in Fig. 1 at 54.

Fig. 6 shows an arrangement for permitting operation of the control equipment at the same time that announcements or program are being transmitted from a studio. In this case operation of relay A at the broadcasting station does not disconnect the voice input circuits of the radio transmitter from the program circuit, but merely inserts a low-pass filter, such as the filter 61, which is shown as adapted to pass only frequencies below 3,500, thus reducing the frequency band from the normal 5,000 or 10,000 cycles to 3,500 cycles. This reduction may be made at the time of announcements without serious effect on the main program to be transmitted. The control frequency, which is here taken as 4,000 cycles for illustrative purposes, would then be transmitted over the program circuit simultaneously with the program and would be selected by its appropriate filter 63 and transmitted to the control apparatus over the circuit 12, as before. The operation of relay A could be controlled by any of the methods which have been described above in connection with Figs. 1, 4 or 5. This arrangement has the advantage that it obviates the necessity of interrupting the program, which interruptions might be objectionable in the case of long programs such as might be broadcast on special occasions.

Although the invention has been described in connection with the disclosure of certain circuits shown in the drawings, it is obvious that many variations may be introduced without departing from the spirit of the invention. For example, the control equipment might be applied not only to radio broadcasting stations to control the radio frequency oscillators, but it might equally well be applied to control sub-master oscillators strategically located about the country, which would in turn act as sources of standardizing control current for the control of broadcasting stations in the adjacent territory.

What is claimed is:

1. In a frequency control system, a plurality of stations each designed to generate waves of a definite frequency, a local generator at each such station, a communication circuit from one point to each of the stations, a source of control frequency waves, means for sending control frequency waves to the stations over the communication circuit during intervals of time not important for other communication over said circuit, and at each station a two-phase motor to compare the frequencies of the local generator

and the said control frequency waves and thereby to adjust the local generator.

2. In a frequency control system, a plurality of stations each designed to generate waves of a definite frequency, a local generator at each such station, a communication circuit from one point to each of the stations, a source of control frequency waves, means for sending control frequency waves to the stations over the communication circuit during periods not used for other communication over the circuit, means for comparing the frequencies of the local generator and the control frequency waves and storing an effect determined by their difference, and means for applying this stored effect to regulate the frequency of the local generator.

3. In a frequency control system, a plurality of stations each designed to generate waves of a definite frequency, a local generator at each such station, a program circuit going to the stations, a source of control frequency waves, means for intermittently sending control frequency waves to the stations over the program circuit, means at each station for comparing said control frequency waves with the output of the local generator, means for storing an effect determined by their difference, and means to adjust the frequency of the local generator by the stored effect.

4. In a frequency control system, a plurality of stations each designed to generate waves of a definite frequency, a local generator at each such station, a program circuit going to the stations, a source of control frequency waves, means for sending control frequency waves to the stations over the program circuit during periods not used for program transmission, and at each station a two-phase motor to compare the frequency of the local generator with the control frequency waves and thereby to adjust the frequency of the local generator.

5. In a broadcast system comprising a plurality of radio stations to be synchronized, a generator of radio frequency oscillations at each station and a program circuit for transmitting programs simultaneously to each of the stations, a source of control frequency of which the frequency normally generated at the stations is a definite multiple, means for intermittently transmitting control frequency currents over the program circuit to each station, a two-phase motor at each station with its windings supplied respectively from the generator at the station and from the said control frequency currents, and means for adjusting the oscillation frequency of the generators at each station in accordance with the comparative effect in the said two-phase motor.

6. In a broadcast system comprising a plurality of radio stations to be synchronized, an oscillation generator at each station and a program circuit for transmitting programs simultaneously to each station, a source of control frequency of which the frequency normally generated at the station is a definite multiple, means for transmitting control frequency currents over the program circuit to each station, storing means responsive to the difference in the frequency of the oscillations generated at the station and the correct multiple of the control frequency, and means operated by said storing means for adjusting the oscillations generated to normal frequency.

7. In a broadcast system comprising a plurality of radio stations to be synchronized, a gen-

erator of radio frequency oscillations at each station and a program circuit for transmitting programs simultaneously to each of the stations, a source of control frequency of which the frequency normally generated at the station is a definite multiple, means for intermittently transmitting control frequency currents over the program circuit to each station, and a two-phase motor for adjusting the oscillation frequency of the generators at each station in accordance with comparison of the local generator frequency and the control frequency during intervals between programs.

8. In a broadcast system comprising a plurality of radio stations to be synchronized, a generator of radio frequency oscillations at each station and a program circuit for transmitting programs simultaneously to each of the stations, a source of control frequency of which the frequency normally generated at the station is a definite multiple, means for intermittently transmitting control frequency currents over the program circuit to each station, and a two-phase motor for adjusting the oscillation frequency of the generators at each station in accordance with the control frequency during relatively unimportant parts of the program.

9. The combination of claim 7 characterized by the fact that the means for adjusting the oscillation frequency at the generator is normally inoperative and is rendered operative by a slow-acting relay during silent periods of the program.

10. The combination of claim 7 characterized by the fact that the means for adjusting the oscillation frequency of the generator at any one station is normally inoperative and is rendered operative during the period of announcements from the station.

11. In a frequency control system, a plurality of stations each designed to generate waves of a definite frequency, a program circuit going to the stations, a source of control frequency waves, said frequency being within the normal frequency band, means for using the program circuit simultaneously for program and control for short intervals of time and comprising means for temporarily limiting the frequency band width of the program and sending the control frequency during these intervals, and means to store an effect due to the control frequency and apply it thereafter to regulate the frequency generated at the respective station.

12. The combination of claim 6 characterized by the fact that the means responsive to the difference frequency adjusts the station frequency to its correct value in a definite short interval of time.

13. The combination of claim 6 characterized by the fact that the storing means responsive to the difference frequency produces a delay of the adjustment, the adjustment being proportional to the said difference frequency and substantially independent of the length of time of the control frequency.

DANFORTH K. GANNETT.