

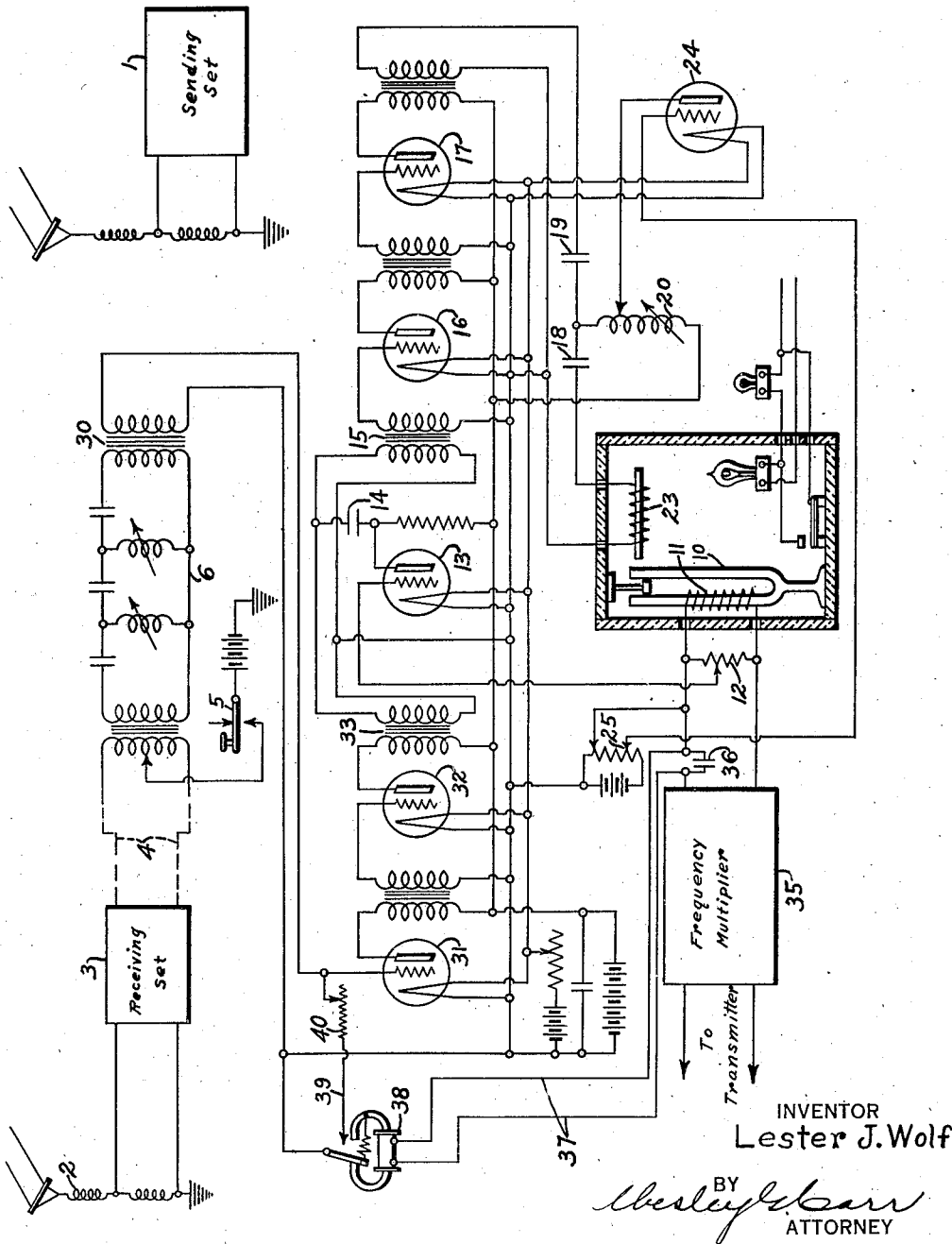
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AUTOMATIC FREQUENCY CONTROLLER

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AUTOMATIC FREQUENCY CONTROLLER

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This invention relates to relaying systems for radio communication and particularly to systems in which two radio transmitting stations at a distance apart are to be maintained at exactly the same wave length.

This invention is an improvement upon the invention of Patent No. 1,781,263, issued November 11, 1930, to the Westinghouse Electric and Manufacturing Company upon an application filed by me.

In the system described in detail in said application, a tuning fork at the home station impresses a modulation upon the energy radiated from said station. This modulation produces, in a receiving set at a short distance from the distant station, a current of a frequency corresponding to that of the fork at the home station. The energy from the receiving set is impressed upon a local oscillation system at the distant station which comprises a tuning fork and regenerative circuits associated with it.

As explained in said co-pending application, the degree of regeneration is so adjusted that the tuning fork at the distant station will be maintained in oscillation even if fading or other cause prevents the impulses from the home station from reaching the regenerative system in the distant station. When this happens, the fork at the distant station, vibrating under the influence of its regenerative circuits, will have the natural frequency of the regenerative system instead of a frequency determined by the fork at the home station.

Although the two forks are adjusted as nearly as possible to the same natural frequency, and the regenerative circuits at the distant station are caused to further so adjust the frequency that the natural periods of the two oscillating systems are very nearly equal, it is not possible to produce absolute equality of these natural frequencies.

Consequently, when, because of fading or other cause, the fork at the home station

ceases to control the fork at the distant station, the two forks will become out of phase. If, after such an event, the interruption ends and the fork at the home station can again produce an influence at the distant station, the incorrect phase relation may cause this influence to tend to stop the fork at the distant station, which would result in an interruption of broadcasting from the distant station.

It is an object of this invention to avoid such interruptions.

It is a further object of this invention to provide automatic means whereby, if the phase of the impulses originating from the fork at the home station and arriving at the distant station is such that the impulses are opposite in sense to the currents in the oscillating system at the distant station, these impulses will be prevented from bringing the fork at the distant station to rest or from materially diminishing its amplitude.

It is a further object of this invention to provide a control device whereby, when the currents generated by the fork and the currents produced by the receiving set at the distant station are subtractively and not additively related, the currents produced by the receiving set will be shunted away from the oscillating system.

Other objects of the invention and details of the construction will be understood from the following description and the accompanying drawing in which the single figure is a diagram of the circuits and apparatus employed.

In the drawing, the sending set 1 is at the home station. It is intended to send out either a frequency produced by a tuning fork at the sending station or a high frequency modulated by the frequency of the fork. The antenna 2 at the receiving station is connected to a receiving set 3 which is tuned to the signals sent out by sending set 1.

The antenna 2 and receiving set 3 are preferably at a distance from the other apparatus at the distant station. Adjustment of the receiving set must, therefore, be controlled over a line 4, and the key 5 is for such control. Between line 4 and the centrally located apparatus at the distant station, a filter 6 is provided. This filter is of the type which will deliver only currents of a frequency determined by the fork at the sending station.

At the distant station the fork 10 is tuned, as closely as can conveniently be done, to the frequency of the fork at the station 1. Details of the provisions for maintaining this fork at constant temperature and thus insuring its constant frequency are described in the above-mentioned co-pending application.

A regenerative system of circuits is provided whereby the fork may be maintained in vibration even when no energy is received from the receiving set 3. These regenerative circuits include a coil 11 mounted upon one tine of the fork. Electromotive forces, developed in this coil by the vibration of the fork, establish currents through the resistor 12 and so impress a potential upon the grid of a tube 13. The potentials amplified by this tube are delivered, through a condenser 14 and a transformer 15, to an amplifying device including tubes 16 and 17 arranged in cascade.

The output of this amplifier is delivered, through a filter, including condensers 18 and 19 in series and an inductor 20 in parallel, to a magnet 23 which drives the fork 10. The inductor 20 is made adjustable in order to assist in controlling the frequency of the fork 10. A still closer control over said frequency is afforded by the tube 24 which is controlled by the grid-biasing device 25.

The energy delivered to the transformer 15 through the tube 13 is supplemented by energy from the transformer 30 which connects the filter 6 to a cascade amplifying system including tubes 31 and 32 and a transformer 33.

The potential across resistor 12 is delivered to the input circuit of a frequency multiplier 35. The frequency multiplier may be of any preferred form but, for my purposes, I have found the form illustrated in Fig. 3 of the above-mentioned co-pending application to be convenient. The multiplier may include a number of vacuum tubes. The input circuit of such a frequency multiplier is connected to the grid and filament of the first of said vacuum tubes.

In the connection to the grid of any of said tubes, a condenser 36 is inserted, and leads 37 from the two sides of the condenser extend to the winding 38 of a relay biased to closed position. For convenience of illus-

tration, this connection to the relay is shown as associated with the input circuit of the frequency multiplier but it may equally well be included in the connection to the grid of any of the tubes in said multiplier.

The contacts of the relay 38 control a shunt 39 which preferably includes a resistor 40, the shunt extending across the grid-filament connection of any one of the tubes between the transformer 30 and the magnet 23. Preferably, however, one of the tubes in the amplifier, between the transformer 30 and the transformer 33, is chosen.

In the operation of the device, the receiving set 3 delivers to the line 4 currents of a frequency determined by the fork in the sending set 1. Preferably, this frequency is very close to the frequency of the fork 10. Any suitable means for adjusting the receiving set 3 may be controlled over the line 4 by means of the key 5, and the receiving set may thus be adjusted to best conditions for delivering impulses of the fork frequency to the filter 6. Impulses of a frequency very different from this will fail to traverse the filter 6. The transformer 30, therefore, will deliver to the tube 31 impulses of only the fork frequency.

Such impulses, amplified by the cascade amplifier including tubes 31 to 17, inclusive, cause the magnet 23 to impress a periodic force upon the fork 10. Since this periodic force is of very nearly the same frequency as the natural frequency of the fork, the fork will have forced vibrations of the frequency of the impulses received over the line 4.

Only a small part of the energy needed to maintain the fork in vibration comes over the line 4. The vibration of the fork, by producing electromotive force in the winding 11, delivers energy, through the tube 13 and condenser 14, to the input circuit of the tube 16. The tubes 16 and 17, with their associated circuits, and the tube 13, with its associated circuits, constitute a regenerative system of circuits which cooperates with the fork 10 to maintain it in vibration.

The regenerative action of this system is sufficient to maintain the fork in vibration, indefinitely or, at least for a period of several seconds after impulses cease to arrive over the line 4. The fork 10 and the tubes 13 to 17, with their associated circuits, may thus be regarded as a local source of oscillation of nearly the same frequency as the impulses arriving over the line 4.

The electromotive force delivered by the coil 11 not only acts upon the tube 13 but also acts upon the frequency multiplier 35. In order that any harmonics of the fundamental frequency which may be useful in assisting in the production of higher frequencies in the frequency multiplier shall not be lost, a condenser 36 bridges an opening in the connection between the coil 11 and the input

terminals of the frequency multiplier. This opening is shunted by the connections 37 and the winding 38.

When the fork is vibrated at its normal amplitude, the current delivered to the winding 38 is sufficient to maintain the contacts of the relay open against the bias thereof. The shunt 39 is, therefore, open and without effect upon the tube 31.

The circuit through the winding 38 extends from the upper end of the resistor 12 through the leads 37 and said winding to the grid of the first tube of the frequency multiplier and from the filament of said tube to the lower end of the resistor 12. The rectifying action of the filament and grid in said first tube gives a unidirectional character to the force exerted by the winding 38 upon the contacts of the relay.

The bias of the relay to closed position may, therefore, properly be a magnetic bias such as polarized relays ordinarily possess. The spring shown upon the drawing may be considered as representing either a mechanical bias or a magnetic bias.

The magnitude of this bias is so chosen that, normally, the current in winding 38 is just sufficient to hold the relay contacts open. The normal condition is that in which the output from the local source comprising the fork and its associated regenerative system of circuits is neither increased nor diminished by energy from the transformer 33.

When fading or failure of the fork at the sending station 1, or any other cause, produces an interruption in the periodic currents over the line 4, no energy is delivered over the transformer 33 to the input of the regenerative system. The energy delivered to the input of the frequency multiplier, that is, the energy delivered at the output of the regenerative system will become somewhat smaller as the amplitude of the fork 10 diminishes because of the failure of energy from the transformer 33. This diminution in the output of the regenerative system will be slow because the regenerative system is nearly sufficient to maintain the fork 10 in vibration at normal amplitude.

Even though the amplitude of the output changes but slightly, the frequency of the output will change. The change in frequency will not be large because the natural period of the local oscillating device is nearly the same as the period of the impulses normally arriving over the line 4. The change in frequency will, however, be enough to produce a beat note in receiving sets listening both to the sending set 1 and the sending set energized through the frequency multiplier 35. This beat note is objectionable but not as objectionable as an interruption of broadcasting from the transmitter supplied through the multiplier 35 would be.

The natural frequency of the local oscillating device is not the same as that of the

currents over the line 4. Consequently, when these currents cease, a slowly varying phase difference will arise between the fork at the sending station 1 and the fork 10. When the fading or other interruption terminates, and impulses again arrive over the line 4, they may no longer be in phase with the currents in the local oscillating device.

Currents from the transformer 33 and from the condenser 14 are added, not arithmetically, but vectorially in the transformer 15. If, therefore, the phase difference be sufficient, the energy delivered to the transformer 15 may actually be less when the interruption is over than it was during said interruption. This will result in a diminution in the amplitude of the vibration of the fork 10.

If the energy delivered over the line 4 is opposite in phase to that delivered over the condenser 14, the diminution in amplitude of the fork may be very rapid. Even if the diminution is not rapid, it will unless prevented, continue until the fork has been brought to rest or nearly to rest. Then, until the fork has had time enough to again build up oscillations in phase with those at the station 1, little or no energy will be delivered to the frequency multiplier 35 and little or no energy will be broadcasted through the transmitter to which this multiplier is connected.

The diminution in current in the output 12 of the regenerative system, which accompanies the diminution in amplitude of the vibrations of the fork, causes a diminution of current in the winding 38, with the result that the relay is no longer able to hold its contacts open against the bias of the relay.

These contacts thereupon close, and a shunt is established across the input circuit of the tube 31. The energy which the amplifier, including the tube 31, would deliver to the transformer 15 is now largely prevented from reaching the amplifier. The resistor 40 is of such magnitude that some energy from the transformer 30 is delivered to the amplifier and, therefore, to the regenerative system, but this energy is insufficient to produce any objectionable diminution in the amplitude of the fork.

While the shunt 39 is closed, the regenerative system including the fork 10, continues to oscillate at its natural frequency, and therefore, continues to change its phase relation to the energy in the transformer 30. After the lapse of sufficient time, not more than a half cycle of the beat note between the two nearly equal frequencies, the phase of the impulses from the transformer 30 and coil 11 will be such that they produce an additive effect in the transformer 15.

Because of the resistor 40 the energy arriving at the transformer 33, when the shunt 39 is closed, is sufficient to produce some in-

crease in the energy of the regenerative system when the phase relation is such that the two currents add. When this occurs, an increase in the amplitude of the fork 10 results. There will, therefore, be an increase in the output of the regenerative system. This includes an increase in current in the winding 38. Therefore the relay 38 will overcome its bias and the shunt 39 will be opened.

As soon as the shunt is opened, full benefit of the energy from the transformer 30 will be received, and the amplitude of the fork 10 will quickly build up to full value, the frequency of the fork 10 being now controlled by the currents in the line 4 and, therefore, producing no beat note in the receiving sets of listeners.

It will thus be seen that, although the relay 38 results in a prolongation of the time during which the listeners hear a beat note, it will prevent the actual interruption of broadcasting service.

The operation has been described with the bias on the relay 38 insufficient to keep the relay contacts closed when normal current is present in the winding 38. An operative system may equally well be made with the relay so adjusted that the current from the fork is normally insufficient to hold the relay open. That is, when no current is being received over the line 4, the current in the winding 38 is just insufficient to cause the contacts to open.

For this adjustment of the bias, the resistor 40 must have somewhat less resistance than for the adjustment used in the operation first described.

An interruption of the current in line 4, such as results from fading, will cause no change in the position of the relay contacts because they are already closed. When, after an interruption, current reappears in the line 4, the presence of the resistor 40 in the shunt will cause this current to produce some effect on the magnitude of the current in winding 38. If this effect is additive, the shunt will open and the currents in line 4 will then have full effect in restoring the frequency of the fork to its correct value. If, on the other hand, these currents are of incorrect phase, the relay contacts remain closed, and the energy delivered through the transformer 33 will be insufficient to produce any marked effect upon the frequency of the fork.

Many variations in the details of the system will be apparent to those skilled in the art and many other applications of the invention besides that specifically described and illustrated will also be apparent. I do not intend, therefore, to be limited except as required by the prior art and as indicated in the accompanying claims.

I claim as my invention:

1. In a synchronizing system, a local os-

cillation device having a natural frequency, a distant source of oscillations of a frequency nearly equal to said natural frequency, means controlled by said distant source for constraining said local device to oscillate at the frequency of said distant source and means for preventing said constraining action from causing an interruption of the oscillation of said local device.

2. In a synchronizing system, a local oscillation device having a natural frequency, a distant source of oscillations, means controlled by said distant source for impressing on said local device periodic energy of nearly the same period as said natural frequency to constrain said local device to oscillate at a frequency determined by said distant source and means for preventing said constraining action from causing an interruption of the oscillation of said local device.

3. Means for controlling the frequency of an oscillating system from a distance, comprising regenerative connections forming part of said system, a frequency-selective receiving device adjusted to be responsive to arriving signals of a frequency approximately that of the natural period of the oscillation system, means for delivering impulses from said receiving set to said regenerative connections and automatic means for diminishing the effect of said impulses upon said oscillating system whenever the sense of the impulses is opposed to that of the oscillations.

4. In a synchronizing system, a device having a natural period of mechanical vibration, a regenerative system associated therewith to maintain said device in vibration, means controlled from a distance for impressing on said regenerative system oscillatory energy of a period nearly equal to said natural period, whereby forced oscillations are maintained in said regenerative system in synchronism with said oscillatory energy, means for diverting said oscillatory energy and means controlled by the resultant current in said regenerative system for controlling said diverting means.

5. In a synchronizing system, a device having a natural period of mechanical vibration, circuits forming with said device a regenerative system constituting a local oscillation device, a distant source of oscillations, a receiving set tuned to respond to energy from said distant source, connections between said receiving set and said regenerative system, whereby oscillatory energy of a period fixed by said distant source will be impressed on said local oscillation device the frequency of said distant source being such that said oscillatory energy will have a period near said natural period whereby said local oscillation device will be constrained to oscillate at a frequency fixed by said distant source, a shunt across said con-

nections, a relay controlling said shunt and output connections from said regenerative system controlling said relay.

6. In a radio relaying system, a transmitter including a frequency-determining portion comprising an oscillation generator, means for impressing energy in accordance with an incoming signal upon said oscillation generator, and means responsive to the output of said oscillation generator for controlling said impressing means.

In testimony whereof, I have hereunto subscribed my name this 23rd day of May, 1928.

LESTER J. WOLF.