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SYNCHRONIZING SYSTEM

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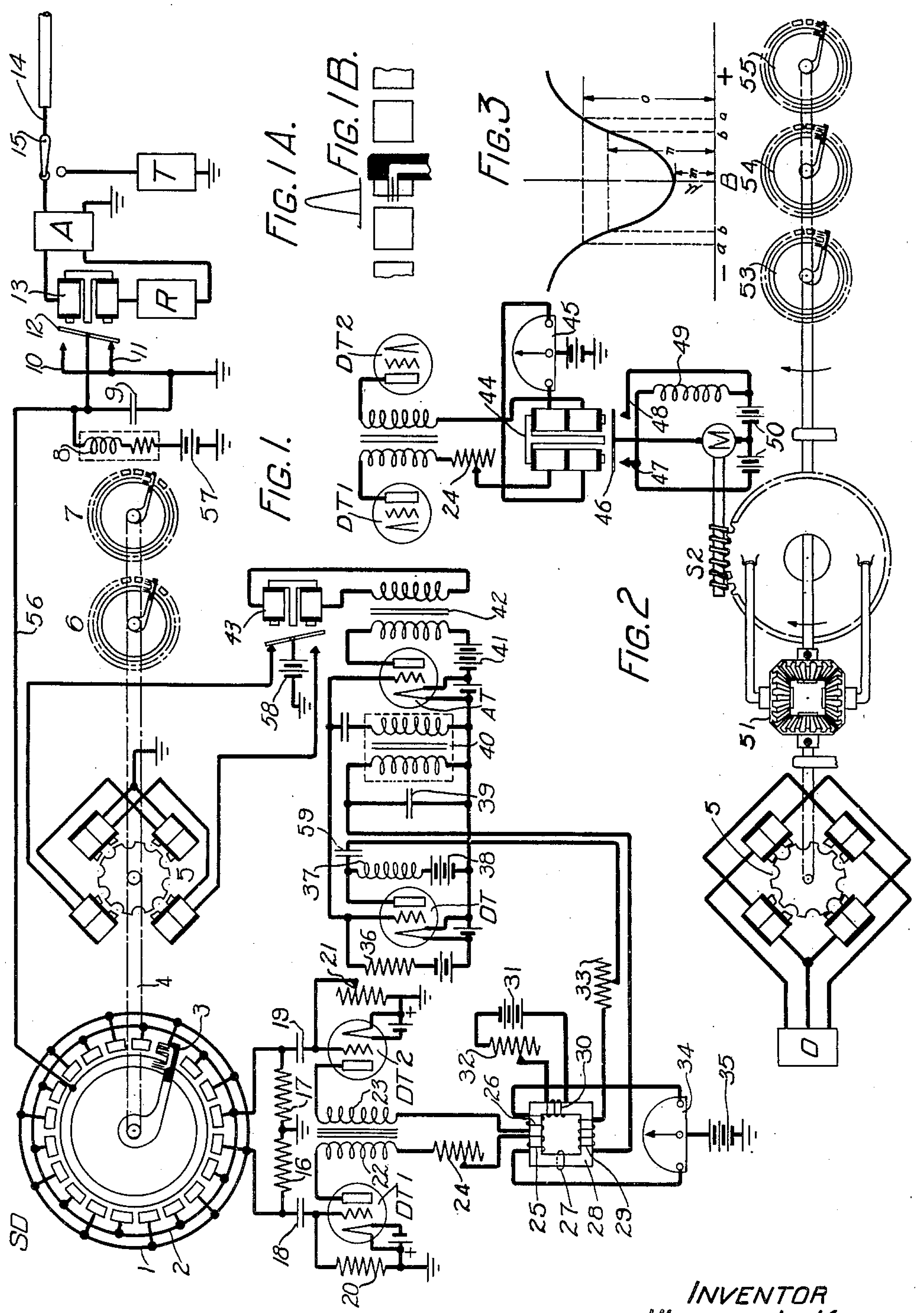

INVENTOR
WILLIAM A. KNOOP
BY J W Schmied
ATTORNEY

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WILLIAM A. KNOOP, OF HEMPSTEAD, NEW YORK, ASSIGNOR TO BELL TELEPHONE LABORATORIES, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

SYNCHRONIZING SYSTEM

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This invention relates to synchronous communication systems and particularly to extremely high speed printing telegraph systems.

A general object of the invention is to maintain in a positive manner and with great exactness synchronism between transmitting and receiving apparatus at separated points.

A more specific object is to continuously maintain synchronism by causing receiving apparatus to run at exactly the same speed as that of associated transmitting apparatus. This is in contrast to systems in which the receiver runs at a speed inherently different from that of the transmitter and is periodically corrected to synchronism with the transmitter.

A feature of the invention is apparatus comprising vacuum tubes which is responsive to extremely small departures from synchronism in either direction for correcting the speed of the receiving apparatus.

Another feature of the invention is an improved method of altering the frequency of a vacuum tube oscillator whereby changes in frequency occur so gradually that any tendency to hunt, of a synchronizing system employing such an oscillator is eliminated.

Heretofore in synchronous telegraphy it has been a general practice to utilize receiving synchronous apparatus adjusted to run at a speed slightly different from that of the transmitting apparatus and to correct for the difference in speed between the two by stepping the distributor brushes backward or forward independently of the driving motor whenever the angular shift exceeded a certain amount. Another practice has been to run the receiving apparatus at one of two speeds which are respectively slower and faster than that of the associated transmitting apparatus and to shift from one speed to the other to maintain approximate synchronism with the transmitter. The phase wander inherent with the above methods prohibits their use in extremely high speed signaling systems when the signal impulses become very short and it then becomes desirable to hold the receiving distributor at substantially the same constant speed as the transmitting distributor. Systems for obtaining this result have been proposed heretofore but they have been subject to the inherent fault that they have depended on correcting impulses received over a distributor segment or segments to operate a correcting relay or other relatively insensitive apparatus. Even the best mechanical relays at present available are only responsive to relatively large impulses compared to those required to control a vacuum tube and therefore it is necessary that the correcting segments in a system of the above type move through a considerable arc in each direction before the contact area between brush and segment becomes large enough to pass sufficient current to operate a relay. This involves an excessive phase displacement, before a correcting impulse is produced.

This insufficiently precise correction has been overcome by eliminating correcting relays and substituting a pair of vacuum tubes the plate circuits of which include two opposing windings associated with the synchronous driving motor. A synchronous correcting distributor applies equal impulses to the grid of each vacuum tube while synchronism is maintained and the plate currents of the two tubes produce equal and opposite effects on the driving motor so that its speed is unchanged. If the distributor commences to drift out of phase with the received signals, however, unequal impulses are applied to the grids of the two tubes so that their plate currents are no longer equal and the resultant unbalance current acts on the driving motor to correct its speed and restore the distributors to synchronism with the received signal impulses.

The system will now be described and its operation explained in connection with the drawing in which Fig. 1 represents a schematic circuit of a complete correcting system in accordance with the invention; Fig. 2 represents a modification of the circuit of Fig. 1, Figs. 1—A and 3 are curves showing characteristics of certain elements of the system and Fig. 1—B shows a detail of the distributing apparatus disclosed in Fig. 1.

In Fig. 1 a signaling conductor 14 which is shown as a submarine cable may be connected to either a transmitter T or a receiving amplifier A by means of switch 15. The output circuit of receiving amplifier A includes a polar relay 13 and signal receiving and recording apparatus R. Relay 13 has an armature 12 connected through an impedance element 8 and a source of potential 57, to ground. Two contacts 10 and 11 associated with the armature 12 are connected to ground. The armature 12 normally lies against one of the contacts 10 or 11 and thus the common ring of the synchronizing distributor SD which is connected to the armature by conductor 56 is normally at ground potential although there is a flow of current from the source of potential 57 through impedance element 8, the armature 12 and a contact of relay 13. When signal impulses are received over conductor 14, however, they cause relay 13 to reverse the position of its armature each time the polarity of the received signals reverses. The impedance element 8 is found to function satisfactorily when it comprises inductance and resistance in series. Hence during the time required for armature 12 to travel from its position against one contact to its opposite position against the other contact, the current through impedance element 8 is broken and the potential of the armature, conductor 56 and the common ring of the distributor SD rises suddenly to a high value. The shape of the impulse thus produced depends on the travel time of the armature 12 and the impedance characteristics of the element 8. Its shape may also be modified by inserting a condenser 9 between the armature 12 and ground. By using a high speed relay and a suitable combination of values of inductance and resistance in impedance element 8 and capacity of condenser 9, an impulse of the general shape of the curve shown in Fig. 1—A may be produced. As shown by comparison of this curve with the Fig. 1—B which is an enlarged, developed portion of the segmental ring of the distributor SD, it will be seen that the synchronizing impulses may be made very steep and of a duration somewhat greater than the time required for the brush 3 of the distributor SD to travel from one segment to the next.

In addition to the synchronizing distributor SD there are mounted on the distributor shaft 4, a synchronous driving motor 5 and receiving and transmitting distributors 6 and 7 which are associated with the receiving and transmitting apparatus R and T respectively. The synchronous motor 5 may be a phonic wheel, the magnets of which are alternately energized from a source of current 58 by a relay 43, the operation of which is controlled by a vacuum tube oscillator OT. This oscillator has a tuned circuit comprising the primary of transformer 40 and condenser 39 and a coupling circuit comprising resistance 33 and winding 29 on a special magnetic core 28. Inductance 37 allows direct current to pass and is of high impedance to alternating current and condenser 59 serve to keep the direct plate current of the tube OT out of winding 29 and transformer 40. The grid of amplifier tube AT is connected in shunt with the grid of oscillator tube OT and therefore repeats oscillatory currents into the relay 43.

Core 28 referred to above is constructed of magnetic material the permeability of which varies with the magnetizing force, and which preferably has a low coercive force in order that slight changes in the magnetizing force may produce corresponding changes in the flux density. Certain nickel-iron alloys heat treated as disclosed in patent to G. W. Elmen 1,586,884, June 1, 1926 have been found satisfactory. A winding 30 on core 28 is connected to battery 31 through a variable resistance 32 and provides a constant magnetizing force for maintaining the flux density of the core 28 at such a mean average value that small changes in the magnetizing force will produce large and approximately proportional changes in the permeability. In other words it is desired to work on the steepest part of the permeability curve. A low resistance winding 27 may be composed of a single short-circuited turn. Its function will be explained later. Windings 25 and 26, wound differentially with respect to each other are connected between a common source of potential 35 through a differential ammeter 34 and the respective plates of two vacuum tubes DT^1 and DT^2. Inductances 22 and 23 are inserted in the plate circuits of these tubes to prevent sudden fluctuations in the plate currents. Variable resistance 24 is inserted in the plate circuit of one of the tubes to equalize the normal currents through the differential coils 25 and 26 in case the characteristics of the tubes DT^1 and DT^2 should differ slightly from each other. The grids of the tubes DT^1 and DT^2 are connected to the filaments of their respective tubes by grid leaks 20 and 21 and through grid condensers 18 and 19 to conductors 1 and 2, which are connected to alternate segments of the distributor SD. Resistances 16 and 17 are connected between the conductors 1 and 2, respectively, and to ground and serve to complete the circuits by which the condensers 18 and 19 impose their potentials on the grids of the tubes. These condensers would otherwise be isolated when not connected to the common ring of the distributor by the brush 3. The segments of the distributor SD are each as nearly half the length of a signal impulse as is possible with the adjacent segments insulated from each other. In normal operation when the system is running in phase with received signals the brush 3 is passing from a segment connected to conductor 1 to a segment connected to conductor

2 at the time a synchronizing impulse is applied to the common ring and brush 3 over the conductor 56 from the armature of the synchronizing impulse relay 13. Hence the synchronizing impulses, as shown in Figs. 1—A and 1—B, are applied equally to conductors 1 and 2 and produce equal effects on the grids of tubes DT^1 and DT^2. The currents in differential windings 25 and 26 remain equal and opposite in effect, although they may both be decreased, and no change is produced in the flux of the core 28 and the impedance of the winding 29 associated with core 28.

Assume that as a result of a change in the period of the oscillator OT, or in the frequency of the received signals, the motor 5 tends to run slow with respect to the signals. This causes the brush 3 to apply more of the synchronizing impulses to conductor 1 and condenser 18 than to conductor 3 and condenser 19. Since the polarity of the synchronizing impulses is always positive they cause the grid of detector tube DT^1 to become momentarily positive and attract to itself electrons from the filament. Therefore, when the positive charge applied to the upper plate of condenser 18 from the synchronizing impulses is removed, either by the brush 3 or the path comprising resistance 16 a negative charge is left on the grid of tube DT^1 which persists for an appreciable length of time, dependent on the resistance of the grid leak 20 and the capacity of the condenser 18. This negative charge on the condenser and grid reduces the plate current flowing in winding 25 and upsets the balance which prevailed between the currents in windings 25 and 26. The differential magnetizing force thus produced in the core 28 changes the total flux in and hence the permeability of core 28. This changes the impedance of winding 29 in the frequency controlling circuit of the oscillator tube OT. The directions of the currents in windings 25 and 26 are so arranged with respect to the direction of the current in the winding 30 that a decrease in current in winding 25, or an increase in current in winding 26 reduces the total flux in core 28, reduces the permeability and magnetic coupling between windings 29 and 27 and hence increases the effective impedance of winding 29. Since winding 29 is inserted in the oscillator feed back circuit, this impedance determines the amount of the energy supplied from the output circuit of tube OT to its input circuit through transformer 40. The average value of the alternating current supplied to the tube varies with the feed back current and the permeability of the transformer decreases with a decrease in the magnetizing current. For instance, referring to Fig. 3, the normal wave impressed on the primary of transformer 40 may be such as to vary the flux density in the core material of the transformer from $-a$ to $+a$ during each cycle and the permeability of the core will vary from the initial permeability M to a definite maximum value O twice during each cycle. On the other hand, if the amplitude of the impressed wave is reduced so that the flux density in the core material varies between $-b$ and $+b$, then the permeability will very between its initial value M and a value N and the average permeability will be less than it was before. Since a decrease in the average value of the current in the transformer winding decreases the average permeability of the core, it decreases the effective inductance of the windings thereon, which inductance together with the capacity of condenser 39 determines the frequency of oscillation. The net effect, therefore, of the decreased current in winding 25 on core 28 is to increase the frequency of the oscillator and the speed of phonic wheel motor 5 until the distributor is restored to the proper phase relation with the received signals, the synchronizing impulses are again divided equally between segments connected to conductors 1 and 2 and the correction circuit is restored to normal.

If the distributor runs faster than the received signals the positive synchronizing impulses are applied to the grid of the detector tube DT^2 and cause its plate current to decrease which has an opposite effect on the flux in core 28, and on the frequency of the oscillator OT. Hence, extremely slight departures from synchronism are effective in changing the average plate currents of tubes DT^1 and DT^2 and producing a compensating effect on the oscillator OT.

A characteristic of the above method of varying the frequency of the oscillator is that a change in the feed back current of the tube OT does not result in an immediate, sudden change in the amplitude, and hence the frequency, of the oscillator wave. This is because the decrement of the tuned circuit comprising condenser 39 and transformer 40 is relatively low and the energy stored in the circuit is relatively large. In other words, this circuit is analogous to a massive tuning fork or a heavy pendulum. A very small amount of power may suffice to maintain the fork or pendulum in uniform vibration whereas an increase in the amount of power supplied produces only a gradual increase in the amplitude. This gradual change in amplitude and frequency is desirable for two reasons. First it helps to average out false corrections. If the correction circuit responded quickly to individual synchronizing pulses, a slight disturbance on a few signals might throw the distributor out of synchronism. It is well known that the effect of disturbance or interference is to advance or retard the signal wave-currents and therefore the time at which the synchronizing pulses are produced. If the correction circuit responds relatively slowly the effect of several false synchronizing pulses will be offset by the large number of equally located pulses which arrive during the response time. Another advantage is that a slow response in frequency gives the grid circuits of the corrector tubes time to fully discharge before the distributor overcorrects. If the oscillator changes its frequency so promptly that the distributor passes through its normal phase position before the grid circuits of the corrector tubes have discharged, overcorrecting and hunting will result.

The short circuited winding 27 is placed on the core 28 in order to make as great a change as possible in the impedance of winding 29. Windings 27 and 29 are coupled by the magnetic flux in the core 28 and the presence of winding 27 introduces resistance in the winding 29, the amount of resistance introduced depending upon the permeability of the core.

An alternative way of causing a change in the permeability of core 28 to produce a large change in the impedance of the feed back circuit is to remove short-circuited winding 27 and insert a condenser in shunt with winding 29 of such value as to almost but not quite tune it to anti-resonance at the normal frequency of the oscillator. A slight change in the inductance of winding 29 produces a large change in the impedance of the anti-resonant circuit.

It was stated above that the oscillator circuit was analogous to a massive tuning fork and applicant has used with success a vacuum tube regenerative tuning fork in place of the oscillator circuit shown. Such tuning forks are well known in the art and comprise a vibrating member with a magnetic pick up coil and a drive coil associated therewith and a vacuum tube amplifier inserted between the pick-up coil and the drive coil. When a fork of this type is substituted for the oscillator circuit shown in the drawing, the winding 29 is inserted in series in the feed back circuit of the fork drive coil substantially in the same fashion as in the oscillator circuit shown.

The above system employs what is known as continuous correction, i. e., the synchronizing system tends to hold the speed of the synchronous driving motor itself in exact synchronism with the received signals. The use of vacuum tubes, however, is not restricted to systems of this type but may also be used to produce discontinuous "clock hand" correction and a circuit for doing this is shown in Fig. 2.

In Fig. 2 a synchronous motor 5 is driven by impulses from an oscillator O which may be a vacuum tube oscillator of the general type disclosed in Fig. 1, or may be an electrically driven tuning fork. Its frequency is adjusted as nearly as possible to that of the received signals but is unaffected by the synchronous correcting apparatus. The synchronous motor 5 drives receiving distributors 53, 54 and 55, two of which may be transmitting and receiving distributors respectively, and the third a synchronous correcting distributor of the type shown at SD in Fig. 1. A differential correcting gear 51 is inserted in the drive shaft between the synchronous motor 5 and the distributors whereby the phase positions of the brushes on the distributors may be shifted with respect to the synchronous motor while the system is in operation. Synchronizing impulses are generated and applied to the vacuum tubes DT^1 and DT^2 exactly as shown in Fig. 1, but the plate circuits of the two tubes include two differential windings on a three position polar relay 44 instead of including differential windings on a core 28 as was shown in Fig. 1. In normal operation equal and opposite plate currents flow in the two windings of relay 44 and the armature 46 of the relay remains in neutral position between contacts 47 and 48. Hence the armature circuit of a motor M, having a field 49 and source of energizing current 50 is open and the correcting differential gear 51 remains stationary. If the distributing brushes lag or lead the received signals however, unequal synchronizing impulses are applied to the grids of DT^1 and DT^2 and cause unequal currents to flow in the two windings of relay 44, as was outlined in connection with Fig. 1. This causes the armature of relay 46 to close on a contact 47, or 48 and pass current through the armature of motor M of such a polarity as to cause it to shift the distributor brushes, through the differential 51, in such a direction as to correct for the phase displacement.

What is claimed is:

1. A system for synchronizing a periodic device with a series of incoming impulses which comprises instrumentalities for producing a series of correcting impulses of the same polarity, one each corresponding to each and every normal change of polarity only of the incoming impulses, and means including correcting circuits whereby each and every one of said series of impulses produces an effect upon said circuits which is nil, acceleratory or retardative in a manner proportional to and depending upon the phase relation of said device with respect to said produced impulses.

2. A system in accordance with the foregoing claim in which the correcting circuits include an oscillatory system of large inertia and a correcting appurtenance operated by the correcting impulses and coupled thereto in such manner that the full correcting effect of a single correcting impulse extends over several cycles of the oscillatory system.

3. In a synchronous telegraph system, syn-

chronizing means comprising means for producing synchronizing impulses of constant polarity from received signal impulses, rotary distributor means, and means for causing said synchronizing impulses to correct for departures from synchronism of said rotary distributor means characterized in this, that it comprises two three-electrode vacuum tubes with their input circuits connected to successive segments of a rotary distributor to which said synchronizing impulses are applied, and with their output circuits including differential windings on an electromagnetic device, and means for driving said distributor, the speed of which is responsive to the flux in said electromagnetic device produced by the difference of the currents in said differential windings.

4. In a synchronous telegraph receiving system, means responsive to changes in polarity of received signal impulses to produce short synchronizing impulses of a single polarity comprising an impedance element, a source of potential, and a polar relay having two fixed contacts, an armature movable therebetween, and an operating winding to which received signal impulses are applied, said source of potential and impedance element being connected in a series path between the armature and the fixed contacts, which are connected together, and means for utilizing synchronizing impulses connected between said fixed contacts and said armature.

5. Means as defined in claim 4, further characterized in that said impedance element comprises inductance and resistance.

6. Means as defined in claim 4, further characterized in that said impedance element comprises inductance and resistance and that a condenser is connected between said fixed contacts and said armature.

7. In a synchronizing system, a source of synchronizing impulses of constant polarity, a synchronous distributor, electromagnetic means comprising two mutually inductive differential windings, contacting means on said distributor for applying said synchronizing impulses equally or unequally to said differential windings dependent on the phase of the distributor relative to the phase of the synchronizing impulses, and means associated with said electromagnetic means and with said rotary distributor responsive to unequal currents in said windings to retard or advance said distributor.

8. In a synchronizing system, a source of syncronizing impulses of constant polarity, a synchronous distributor, two three-electrode vacuum tubes having input circuits and output circuits, electromagnetic means comprising two mutually inductive differential windings with each of said windings connected in the output circuit of one of said tubes, means on said distributor for applying said synchronizing impulses equally or unequally to the input circuits of said tubes dependent on the phase of the distributor relative to that of the synchronizing impulses, and means associated with said electromagnetic means and with said rotary distributor responsive to unequal currents in said windings to retard or advance said distributor.

9. Means as defined in claim 8, further characterized in that the input circuit of each of said vacuum tubes comprises a condenser in the grid lead and a leak resistance between the grid and cathode.

10. In a synchronizing system, a source of synchronizing impulses of constant polarity, synchronous distributing means comprising a contact successively contacting with two conductors, a condenser connected to each conductor, electromagnetic means comprising two mutually inductive differential windings a source of potential, two vacuum tubes, each having a plate connected through one of said differential windings and said source of potential to its cathode and having a grid connected to one of said conductors on said synchronous distributor through the condenser associated therewith, a resistance connected between the grid and cathode of each tube, a second resistance connected between each conductor of said synchronous distributing means and the cathode of the associated tube, a connection between the cathode of each tube and one terminal of said source of synchronizing pulses and a connection between the other terminal and the contact of said synchronous distributing means, and means associated with said electromagnetic means and with said distributing means responsive to unequal currents in said differential windings to retard or advance said distributing means.

11. In a synchronizing system, a source of synchronizing impulses of constant polarity, a source of electrical oscillations comprising a tuned circuit, means comprising two differentially arranged conductors associated with said tuned circuit whereby unequal currents in said conductors alter the impedance characteristics of said tuned circuit, and synchronous selector means driven from said source of electrical oscillations for applying said synchronizing impulses equally or unequally to said differential conductors dependent on the phase of the selector means relative to the synchronizing impulses.

12. In a synchronizing system, a source of synchronizing impulses of constant polarity, a source of electrical oscillations, a frequency controlling circuit for said circuit comprising as a portion thereof a winding having a core of magnetic material the permeability of which varies with the magnetizing force, a second and a third winding on said core differentially wound with respect to each other, and selector means controlled by said electrical oscillations to apply said synchronizing

impulses equally or unequally to said differential windings, dependent on the phase of the selector means relative to the synchronizing impulses.

13. Means as defined in claim 12, characterized in that said core of magnetic material has a fourth winding with a source of manually variable current connected thereto.

14. Means as defined in claim 12, characterized in that said core of magnetic material has a fourth winding with a source of manually variable current connected thereto, and a fifth, short-circuited, winding of low resistance.

15. In a synchronizing system, a source of synchronizing impulses of constant polarity, a source of electrical oscillations comprising a three-electrode vacuum tube having a tuned circuit comprising inductance and capacity, a feed back circuit for supplying energy from the plate circuit of said tube to the grid circuit, whereby continuous oscillations may be generated, a second tube having its cathode and grid connected in parallel with the grid and cathode of the first tube, a winding having a core of magnetic material, the permeability of which varies with the magnetizing force connected in the feed back circuit of said oscillator tube, a second and a third winding on said core differentially wound with respect to each other, a rotary distributor comprising a brush moving over a segmented ring, alternate segments of which are connected together, a connection between said distributor brush and said source of synchronizing impulses, means connected between each set of segments and said second and third windings respectively whereby impulses applied to said segments control currents in said windings, a synchronous motor for driving the distributor, and means in the output circuit of said second vacuum tube for applying current impulses to said synchronous motor.

16. The method of causing a synchronous device to remain closely in phase with another synchronous device by means of a circuit including an inductance element having a magnetic core which comprises causing increments of departure from synchronism to produce corresponding increments of change of unidirectional flux in said core.

17. A source of electrical oscillations comprising an amplifier having a feed back circuit and a separate and distinct frequency determining circuit comprising an inductance element with a core of magnetic material the permeability of which varies with the flux density in combination with a periodically operating mechanical device and means whereby perturbations in the periodicity of said device change the flux density of said core.

18. An oscillator comprising a vacuum tube amplifier having a feed back circuit for transferring energy from the output to the input circuit thereof, a tuned circuit associated with said tube for determining the frequency of oscillation thereof, comprising a capacity element and an inductance element having a core of magnetic material the permeability of which varies with flux density, means for excluding direct current from said inductance element and means for varying the frequency of said oscillator comprising a variable impedance element in said feed back circuit in combination with a source of impulses and a periodically operating device and means whereby departures from a fixed state of synchronism between said impulses and the operation of said device change the impedance of said variable impedance element.

19. A system for maintaining a local device in synchronism with synchronizing impulses comprising means for producing a series of impulses having characteristics varying in a manner dependent upon and in proportion to any departure from synchronism, a device of variable impedance characteristics, and means for varying the impedance thereof in accordance with the varying characteristics of said series of impulses, an oscillation generating device, connections between said oscillation generating device and said local device, said connections including a magnetic element controlling in accordance with its impedance the frequency of said oscillation generating device, and connections whereby said device of variable impedance characteristic controls the impedance of said magnetic element.

In witness whereof, I hereunto subscribe my name this 1st day of February, 1928.

WILLIAM A. KNOOP.