

March 25, 1941.

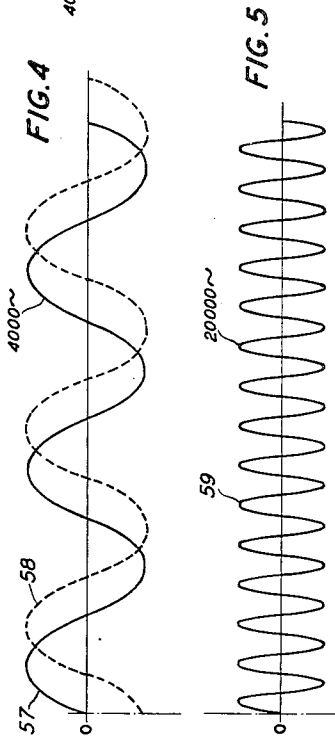
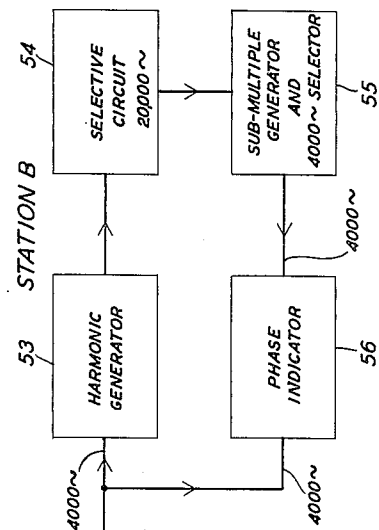
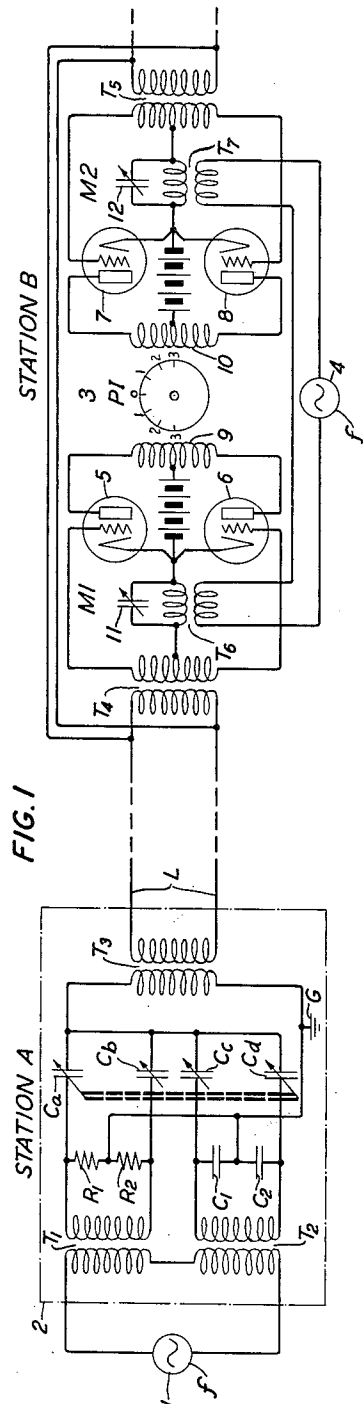
W. A. MARRISON

2,236,374

REMOTE INDICATION AND CONTROL

Filed Jan. 12, 1937

2 Sheets-Sheet 1



INVENTOR
W. A. MARRISON
BY *H. A. Burgess*
ATTORNEY

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W. A. MARRISON

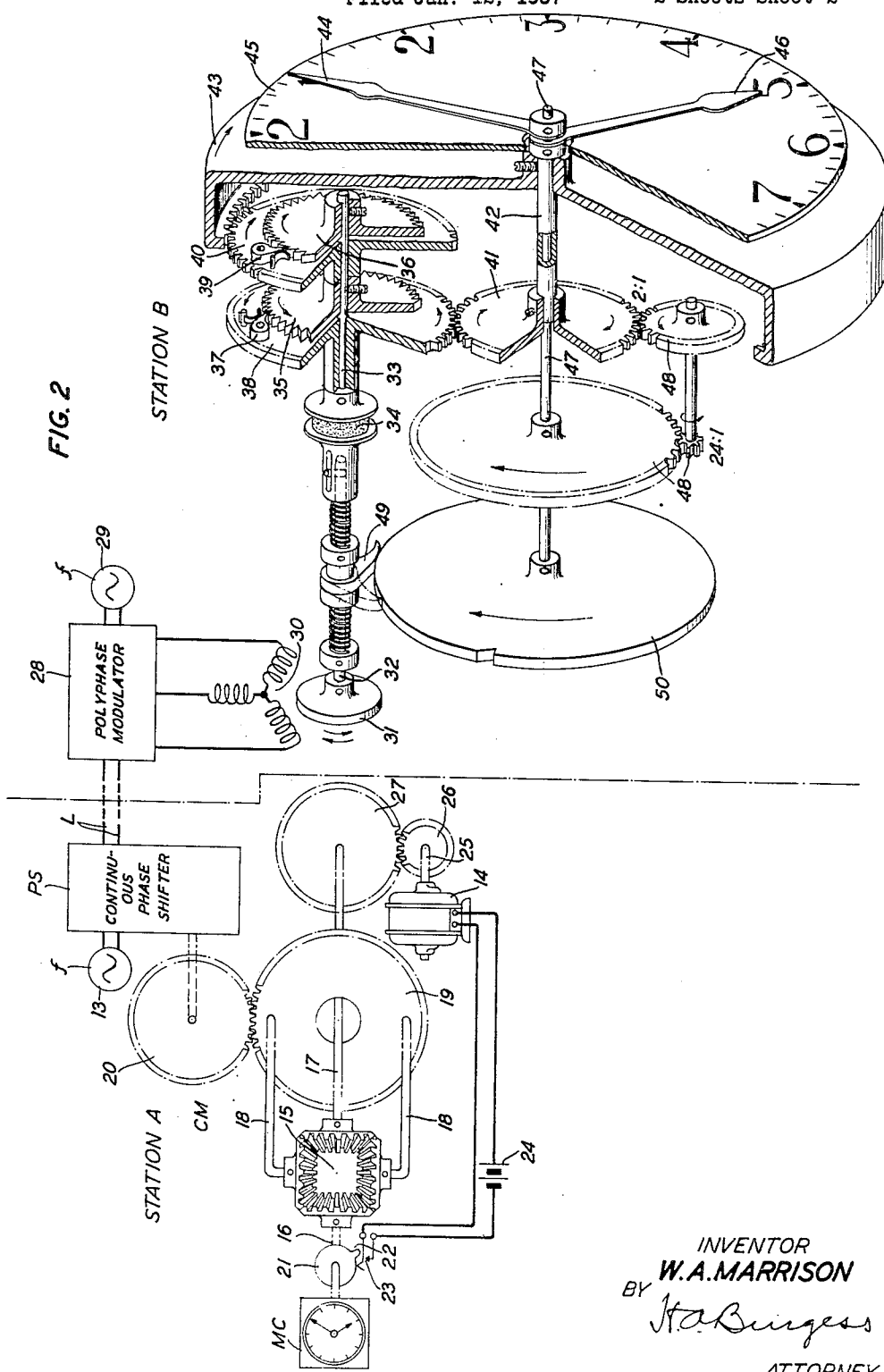
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2 Sheets-Sheet 2

FIG. 2



INVENTOR
W.A. MARRISON
BY *H. Burgess*
ATTORNEY

UNITED STATES PATENT OFFICE

2,236,374

REMOTE INDICATION AND CONTROL

Warren A. Marrison, Maplewood, N. J., assignor to
Bell Telephone Laboratories, Incorporated, New
York, N. Y., a corporation of New York

Application January 12, 1937, Serial No. 120,186

5 Claims. (Cl. 177-337)

This invention relates to signaling systems and particularly to such systems in which signaling energy is transmitted to remote points for the purpose of indication or control.

An object of the invention is to accurately control indicating or other apparatus from a remote point.

Another object is to control indicating or other apparatus from a remote point by a method involving continuous or intermittent phase displacements of the control energy at a transmitting point.

Frequently an indication of a continuous process at two or more points simultaneously is desired. Examples of this are metering systems in which an indication of the process at one station may be desired at one or more remote stations for the purpose of supervision, or time indicating systems requiring synchronization at a number of separated points. The methods that are in use for this sort of service are not readily adaptable to multiplex operation.

In accordance with the present invention, indication or control of operations at one or more points in a system is attained from a remote point by a method involving phase displacement of an alternating current wave under control of the signal or other energy, the variations of which it is desired to indicate or use for control.

The method in general consists in transmitting from a control point to other points in the system an alternating current the frequency of which is constant except for controlled phase displacements proportional to the variations in the signaling or other control energy, produced by a continuous or intermittent phase shifter in the transmitter. The phase variations in the received waves relative to a standard, a wave of substantially the same frequency but unshifted phase, at the distant station are determined and used to produce the desired indication or control. This method is well adapted for multiplex operation and can be operated over any message circuit.

A more complete understanding of the various features of the invention may be obtained from the following detailed description thereof when read in connection with the accompanying drawings, in which

Fig. 1 is a schematic diagram of a system of indication in accordance with the invention;

Fig. 2 shows in more detail the application of the invention to a time service system;

Fig. 3 is a block diagram of a modification of the system of the invention shown in Fig. 1; and

Figs. 4 and 5 show curves illustrating the operation of the system of Fig. 3.

Fig. 1 shows a system of indication by phase displacement. In the system of Fig. 1, the transmitting station A is connected with a remote receiving station B over the signal transmission circuit or line L. At the transmitting station A an alternating current of constant frequency is generated by the generator 1 and is transmitted through the continuous or intermittent phase shifter 2 to the transmission circuit L, the phase shifter providing phase displacement in the transmitted alternating current wave proportional to the variations in signal or other variations to be indicated at station B.

The particular phase shifter illustrated is similar to that disclosed in United States Patent 2,004,613, issued June 11, 1935 to L. A. Meacham, although any other type of phase shifting apparatus which is adapted to continuously or intermittently vary the phase of an impressed alternating current over the desired angular range may be employed. As indicated, the phase shifter 2 comprises two input transformers T₁ and T₂ of like characteristics designed to transmit efficiently the constant frequency f of the alternating current source 1, connected across the two primary windings of the transformers in series. The secondary winding of transformer T₁ is terminated in the equal series resistances R₁, R₂ and the secondary winding of transformer T₂ is terminated in the equal series capacitances C₁, C₂, these resistances and capacitances being related to each other by the expression

$$R_1 = R_2 = \frac{1}{\omega C_1} = \frac{1}{\omega C_2} \quad (1)$$

where $\omega = 2\pi f$.

The common terminal of the resistances R₁, R₂ and the common terminal of the capacitances C₁, C₂ are connected to ground, G, or are otherwise fixed in potential, and to the lower terminal of the primary winding of the output transformer T₃. The stator plates of the four variable capacitors C_a, C_b, C_c, and C_d are respectively connected to the upper terminal of resistance R₁, the lower terminal of resistance R₂, the upper terminal of capacitor C₁ and the lower terminal of the capacitor C₂, and the rotors of the variable capacitors C_a, C_b, C_c and C_d are all connected to the upper terminal of the primary winding of output transformer T₃. The secondary winding of output transformer T₃ is connected to the input of the transmission circuit L.

The effect of the above-mentioned connections in the phase shifter 2 is to provide at the stator

plates of the variable capacitors C_a , C_b , C_c and C_d potential differences which, with respect to ground, will be equal in amplitude, but will have phase angles spaced at intervals of 90 degrees, the relative phase positions at these plates being respectively 0, 180, 90 and 270 degrees. The rotor of each of the capacitors C_a , C_b , C_c and C_d is preferably so shaped that its capacitance varies sinusoidally with respect to the angular displacement of the rotor, and the rotors are arranged to have a unitary control for varying their angular displacement simultaneously, as indicated by the dotted line U connecting the arrows, for example, by mounting them on a common shaft.

By operation of the unitary control, as by rotating the common shaft of the rotors, the phase of the output wave of the phase shifter 2 relative to its input wave can be shifted continuously by any desired angle, however large, and at any suitable rate. In the particular type of phase shifter described, the reactance of the four parallel capacitors C_a , C_b , C_c and C_d , due to the displacement of the rotors thereof by fixed angles of 90 degrees, will remain constant in magnitude for all settings of the unitary control (angle of rotation of common rotor shaft), and the alternating potential obtained from the terminals of the secondary winding of the output transformer T_3 will be constant in amplitude and have a phase angle variable through an unlimited range, the phase of the output voltage being directly proportional to the angular displacement of the rotors of the variable capacitors produced by the unitary control.

By any suitable means (not shown) the unitary control of the phase shifter 2 is controlled by the signals or indications to be transmitted so that the phase displacement of the alternating current wave of frequency f impressed by the phase shifter on the input of the circuit L varies in accordance with variations in the signals or indications.

The alternating current wave varying in phase in the output of the phase shifter 2 is transmitted over the transmission circuit L to station B.

The circuit L may be any type of message circuit, as the signal to be transmitted comprises only a single frequency or a narrow band of frequencies with (in general) slow phase modulation. For continuous remote metering or the like systems, where the variations are by nature continuous, the total variation in the frequency of the signal wave would be such that it could be transmitted in a narrow frequency band. Thus for general purpose remote indication and control, a large number of channels could be operated simultaneously over a single physical or phantom circuit.

The phase variations in the received wave will be detected at station B and utilized to control apparatus giving an indication of the variations in the signals at station A, by the receiving apparatus 3, similar to that disclosed in applicant's Patent No. 1,762,725, issued January 10, 1930.

The apparatus 3 comprises a source 4 of alternating current waves of the same nominal frequency, f , as the alternating current waves received over the transmission circuit L, but of constant or substantially constant phase, two duplex modulating devices M_1 and M_2 , or the equivalent, and the polyphase indicator PI.

The particular type of modulating device M_1 illustrated comprises a pair of three-electrode space discharge devices 5 and 6 having their input circuits connected in push-pull relation

through the secondary winding of the input transformer T_4 , the primary of which is connected to the output of the transmission circuit L, and the modulating device M_2 comprises the two three-electrode space discharge devices 7 and 8 having their input circuits connected in push-pull through the secondary winding of input transformer T_5 , having its primary winding connected across the output of transmission circuit L in parallel with the primary winding of input transformer T_4 . The output circuits of the tubes 5 and 6 of the modulator M_1 are connected in push-pull relation respectively through the upper and lower halves of the input winding 9 of the indicator PI, and the output circuits of the tubes 7 and 8 of modulator M_2 are connected in push-pull relation respectively through the upper and lower halves of the input winding 10 of the indicator PI.

Alternating current waves of the same frequency f as the waves incoming over the transmission circuit L, but of substantially constant phase, from the generator 4 are impressed on the common portion of the input circuits of the tubes 5 and 6 in modulator M_1 and the common portion of the input circuits of tubes 7 and 8 of modulator M_2 by transformers T_6 and T_7 , respectively, the primary windings of the two transformers being connected in series. The phase of the inputs to modulators M_1 and M_2 through transformers T_6 and T_7 is adjusted with respect to the inputs to the modulators M_1 and M_2 through the parallel transformers T_4 and T_5 , in any suitable manner, for example, by adjustment of the values of the variable capacities 11 and 12 respectively connected across the secondary windings of transformers T_6 and T_7 , so that there is a 90 degrees relative phase shift between the two inputs.

Currents comprising combination products of the two inputs applied to modulator M_1 through transformers T_4 and T_6 , respectively, flow through coil 9 in the output of that modulator, and currents comprising combination products of the two inputs applied to modulator M_2 through transformers T_5 and T_7 , respectively, flow through coil 10 in the output of the latter modulator. The vector arm of these two output currents has a phase angle which varies with the difference between the two input currents. The polyphase indicator PI will be rotated under joint control of the currents in the coils 9 and 10 in a direction and by an amount depending on the direction and amount of relative phase shift between the inputs to modulators M_1 and M_2 , thus giving an exact indication of the variations of the signals or other indications producing the phase displacements at station A.

Fig. 2 shows a synchronized time service system employing the method of phase displacement of the invention. There is shown in the figure a central or master station A at which the master time signals are generated and one secondary station B of a plurality of such stations in the system, connected with the central station A over the transmission line L. At station B is located time indicating apparatus to be synchronized with the time signals produced at the central station A.

A good synchronized clock system should include means for advancing the indicating mechanism at the secondary station continuously or in small substantially equal steps, and also means for periodic checking so that the indicator will never show incorrect time for any extended period

even though a circuit failure should stop the mechanism temporarily. This requires that two types of control signals be transmitted from the master clock at the control station to the secondary clocks at the secondary stations, and that selective means be employed to distinguish between the signals and to act upon them. In the mechanism of Fig. 2 to be described, the signals that are used to control the regular time indications are positive (leading) phase displacements, while those used to check, and if necessary adjust, are negative (lagging) phase displacements.

The apparatus at the central station A includes a master clock MC, the time indications of which are to be transmitted to the secondary station B, a source of alternating current waves 13 of constant frequency f , a phase shifter PS for producing positive (leading) or negative (lagging) phase displacements in the waves of frequency f from source 13 prior to their transmission over line L, and control mechanism CM for controlling the phase shifter PS to make the phase displacements produced thereby in the transmitted waves proportional to the variations in time indicated by the master clock MC.

The continuous phase shifter PS may be of the type indicated within the dot-dash box 2 in the system of Fig. 1.

The continuous phase shifter PS is arranged to be adjusted by control mechanism CM under control of the master clock MC and the motor 14 separately.

The master clock MC normally advances the phase shifter PS at a rate corresponding to its progressive time variations or corresponding to the required motion of the remote time indicator at station B. The motor 14 and associated apparatus is provided to reverse the motion of the phase shifter PS for a short interval of time at each checking period. For both operations use is made of the control mechanism CM, which may be a modification of a well-known differential gear assembly shown in the drawing in parallel perspective.

In the control mechanism CM, the differential beveled gear arrangement 15 is interposed between the shaft 16, which is adapted to be rotated by any suitable means in accordance with time changes of the master clock MC, and shaft 17, and the gears that link these two shafts together are mounted on a supporting frame 18 secured to a gear wheel 19 which meshes with a gear wheel 20. The rotation of gear wheel 20 in one direction adjusts the phase shifter PS to produce proportional positive phase displacements in the wave supplied by source 13, and its rotation in the opposite direction adjusts the phase shifter PS to produce proportional negative phase displacements in that wave.

Any change in the angular position of the shaft 16 with variation in the time indication of the master clock MC, through the beveled gears 15 and frame 18 correspondingly changes the angular position of the gear wheel 19. This causes the gear wheel 20 meshing therewith to rotate advancing the phase shifter PS at a corresponding rate, thus causing the alternating current wave from the source 13 transmitted over the line L to have phase displacements proportional to the time variations of the master clock MC.

Mounted on the shaft 16 is a cam 21 having a projection 22 thereon which during each revolution of the shaft 16 under control of the master clock MC causes the engagement of the contacts 23 to connect a source of energizing current 24

to the motor 14 causing the operation of the latter. The motor 14 through its shaft 25 rotates gear 26 causing the gear 27 meshing therewith to rotate shaft 17 in such direction as to control the differential gears 15 in the opposite manner to that which occurs when they are driven directly by shaft 16. This reverses the direction of rotation of gear 19 and thus of gear 20 so that the adjustment of the phase shifter PS is reversed for a short interval of time. This causes proportional negative phase displacements to be made during that interval in the wave transmitted over the line L, which, in the manner to be described later, are used to adjust indicating apparatus at station B to correct for deviations in the indicated time from that of the master clock MC at station A. By proper design of the cam 21 and the associated apparatus the time interval between, and the duration of, the checking signals can be made of the proper values as determined by experiments with actual clock systems. In a particular case they could, for example, recur every hour and last for say five seconds, which would be sufficient time to correct for an error of as much as an hour in the indicated time.

The alternating currents of frequency f from the source 13 with the phase displacements therein are transmitted over the line L to the secondary clock station B.

At station B the received waves are fed into the polyphase modulator 28 in which they are combined with alternating current waves of the same frequency f as generated by the source 13 at station A but of substantially constant phase, supplied from the local source 29. The latter waves are supplied to the input of the polyphase modulator 90 degrees out of phase with respect to the incoming waves from line L. The polyphase waves produced in the output of the modulator control the rotation of the rotor 31 of the polyphase motor 30 in a direction and amount corresponding to the direction and difference in phase between the two input waves to the modulator.

The polyphase modulator 28 and the polyphase motor 30 controlled thereby may be of the type described in the United States Patent 1,959,449, issued to H. M. Stoller on May 22, 1934.

The rotor element 31 rotates a shaft 32 which, in turn, controls the rotation of a shaft 33 through the friction clutch 34. Fixed to the shaft 33 are the two ratchet wheels 35 and 36. The ratchet wheel 35 engages a pawl 37 to rotate a gear wheel 38 in the counter-clockwise direction when the shaft 33 is rotated counter-clockwise, while the ratchet wheel 36 engages a pawl 39 to rotate a gear wheel 40 in the clockwise direction when the shaft 33 is rotated clockwise. Thus one or the other of the gear wheels 38 and 40 will be rotated when shaft 33 is rotated. Both gears 38 and 40 are freely rotatable about the shaft 33. The opposite direction of rotation of the two gear wheels 38 and 40 is due to the opposite disposition of the ratchet teeth on ratchet wheels 35 and 36.

The gear wheel 38 meshes with the gear wheel 41 rotating the latter in the clockwise direction when the former is rotated counter-clockwise, thus rotating the shaft 42 of gear wheel 41 in the clockwise direction. The gear wheel 40 meshes with a gear 43 also affixed to the shaft 42 in such manner as to rotate the latter also in the clockwise direction when the shaft 33 is rotated clockwise. The relative diameters of the gears 41 and 43 are such that the shaft 42 rotates slowly in the clockwise direction when the shaft 33 rotates in

the clockwise direction, while the shaft 42 rotates quickly in the same direction if the shaft 33 is revolved in a counter-clockwise direction. An indicating hand 44 representing the minute hand of the clock 45 is fixedly attached to the shaft 42, whereas an indicating hand 46 representing the hour hand of the clock 45 is fixedly attached to a shaft 47, the latter shaft and thus the hour hand 44 of the clock 45 by means of the set of reduction gears 48 associating the shaft 47 with the gear wheel 41 attached to shaft 42, being rotated at one-twelfth the speed of the shaft 42 and thus of the minute hand 44. Thus, the hands 44 and 46 of the clock 45 are rotated clockwise in an amount proportional to the phase displacements of the alternating current waves incoming over the line L and therefore their indications are synchronized with the indications on the master clock MC at the controlling station A.

Normally, the phase advance is just sufficient to keep the time indication correct. However, should there be a brief circuit failure, the reading of the indicating clock at station B will lag behind the correct position by an amount proportional to the duration of the circuit failure. Any such error is corrected by retarding the phase of the alternating current transmitted from station A over the line L for a brief period at predetermined intervals under control of the motor 14 and cam arrangement 21 at station A, previously referred to, which results in the hands 44 and 46 of clock 45 being advanced to a definite position corresponding to the correct time (at time of checking) in the following manner.

The cam 21 associated with the shaft 16, the rotation of which is controlled by master clock MC at station A, causes at predetermined intervals the engagement of contacts 23. When this happens the motor 14 is energized from source 24 and operates to rotate its shaft 25. The rotation of the latter through gears 26, 27, 15, 19 and 20 in the manner previously described controls the phase shifter PS to retard the phase in the alternating current supplied from the source 13.

The phase retarded current passing over the line L is combined at station B in the polyphase modulator 28 with the alternating current waves of constant phase from the local source 29, in the manner previously described, to control the polyphase motor 30 to rotate its rotor member 31 in the counter-clockwise direction. The shaft 32 and thus the shaft 33 by operation of the friction clutch 34 are thus rotated also in the counter-clockwise direction. The ratchet wheel 35 fixed to the shaft 33 rotating in the counter-clockwise direction engages pawl 37 to rotate the gear 38 in the counter-clockwise direction also. This will cause gear 41, shaft 42 and shaft 47 to be rotated in the clockwise direction, as previously described, advancing the hands 44 and 46 of the clock 45 quickly, due to the relative size of gears 38 and 41, to the correct position.

The clockwise rotation of the shaft 47 causes the rotation of the single tooth ratchet wheel 50 in the clockwise direction. The pawl 49 is so associated with the shaft 32 that it will not engage with the single tooth of ratchet wheel 50 when the shaft 32 is rotated by rotor 31 of the polyphase motor 30 in the clockwise direction. However, when the shaft 32 is being rotated in the counter-clockwise direction, the condition now being described, the pawl 49 is thrown over so as to be in a position to engage with the ratchet wheel 50 rotating in the clockwise direction.

When the pawl 49 finally engages the single tooth

of ratchet wheel 50, the hands of the clock 45 will be in a definite position and cannot be further advanced. Thus, the time mechanism is prevented from being reset too far.

While the shaft 32 continues to rotate in a counterclockwise direction, the shaft 33 normally rotated by the shaft 32 through the friction clutch 34 does not revolve due to the stationary position of gears 41 and 38 as a result of the engagement of the pawl 49 with the single tooth of the ratchet wheel 50. Preferably, the retardation in the phase of the alternating current received at station B over the line L is for a sufficient period to insure the rotation of the shaft 42 for one complete revolution. Although the correction for the condition illustrated would be effected every twelve hours, by suitable design of the cam 21 and associated apparatus the correction can be obtained for any period, for example, every hour. In this latter case, the ratchet wheel 50 would be fixedly attached to the shaft 42.

After the periodic checking, the contacts 23 are disengaged with further rotation of the projection 22 on cam 21, and the phase shifter PS will continue to advance the phase of the alternating current from source 13 under control of the master clock MC as described hereinbefore, causing the rotor 31 of the polyphase motor 30 at station B to be again rotated in the clockwise direction. The pawl 49 will then be rotated in a clockwise direction to disengage the ratchet wheel 50. The hands 44 and 46 of clock 45 will then be advanced to indicate time corresponding to the position of the hands of the master clock MC at station A in the manner previously described.

Fig. 3 illustrates diagrammatically a modification of the system of Fig. 1 in which the alternating current wave of constant phase used at the receiving station as a standard of comparison for determining the phase displacements in the transmitted wave is derived from the latter wave, and in which the frequency of the derived wave is not affected by the phase shifts in the transmitted wave.

At station A, in Fig. 3, a source 51 supplies an alternating current wave of constant frequency f , say 4,000 cycles, to a phase shifter 52 which is adjusted in accordance with the signal variations to be transmitted, in a manner similar to that described in connection with the system of Fig. 1, to produce phase displacements, positive or negative, in the waves in response to signal variations in multiples of a unit phase shift,

$$\frac{2\pi}{n}$$

radians, where n is any integer greater than 2, each unit corresponding to a unit variation in the signal. The particular unit used will depend on the ratio of the base frequency to the higher frequency used to produce the comparison frequency at the receiving station.

The alternating current wave with varying phase displacements in the output of the phase shifter 52 is transmitted over the line L to the station B. A portion of the incoming phase-shifted wave at station B is impressed on the input of the harmonic generator 53, and another portion on the phase indicator 56. The harmonic generator 53, which may be of any of the well-known types, is used to produce harmonics of the 4,000-cycle impressed wave, one of which, nf , in this case 20,000 cycles, is selected by the selective circuit 54 in the output of the harmonic generator 53, and is impressed on the input of the sub-

multiple generator 55 which is adapted to produce sub-multiples of the 20,000-cycle frequency including the sub-multiple frequency, 4,000 cycles.

The sub-multiple generator 55 may be of any suitable type, for example of the multi-vibrator type similar to that disclosed in United States Patent 2,022,969, issued to L. A. Meacham, December 3, 1935.

The 4,000-cycle sub-multiple frequency is selected from the output of the sub-multiple generator and is impressed on the phase indicator 56, which may be of the type disclosed at station B in the system of Fig. 1, in which it is compared with the 4,000-cycle wave with varying phase displacements impressed thereon from the output of the line L, to determine the phase displacements in the latter wave, corresponding to the signal variations at station A, and to produce corresponding operations of a suitable indicating means in a manner similar to that described in connection with the system of Fig. 1.

If the unit phase shift produced in the constant frequency 4,000-cycle wave by the phase shifter 52 at station A is 72 degrees, the change of 72 degrees or multiples thereof in the base frequency corresponds to one whole cycle at 20,000 cycles. Therefore, phase changes of ± 72 degrees in the 4,000-cycle current do not appear in the 20,000-cycle current produced by the harmonic generator 53 at station B. The 4,000-cycle sub-multiple of the 20,000-cycle wave in the output of the sub-multiple generator 55 at station B, accordingly, is in phase with the 4,000-cycle standard current fed to the phase shifter 52 from the source 51 at station A.

The operation of the system of Fig. 3 will be clear from the curves of Figs. 4 and 5. In Fig. 4, the solid curve 57 represents the 4,000-cycle current produced by the standard source 51 at station A in the system of Fig. 3, while the dotted line 58 represents the same 4,000-cycle current when it has been advanced in phase by the phase shifter 52 by 72 degrees. The solid curve 59 in Fig. 5 represents the 20,000-cycle current selected by the selective circuit 54 from the output of the harmonic generator 53 at station B in the system of Fig. 3. It will be seen that the phase shift of 72 degrees in the wave impressed on the harmonic generator 53 is not reflected in the curve 59, for the 72-degree shift corresponds to one whole cycle at 20,000 cycles. As indicated, the 4,000-cycle submultiple of the 20,000-cycle frequency in the output of the sub-multiple generator 55 at station B in the system of Fig. 3, therefore, is in phase with the 4,000-cycle wave of unshifted phase produced by the generator 51 at station A.

The systems of the invention as described above are adaptable to a large number of uses other than those specifically referred to, for example in telautography, message signaling, standard frequency supply systems, inter-city telephone dialing and inter-office signaling for all purposes, and for the simultaneous control of switching carrier frequencies used in privacy signaling systems.

Among the advantages which may be attained by the methods of the invention are low cost of individual channels, and the ease of transmitting a signal which may be required to integrate continuously in either direction and, when necessary, to vary continuously through zero.

While the preferred embodiments of this invention have been illustrated and described, va-

rious modifications thereof within the spirit and scope of the invention will be apparent to persons skilled in the art.

What is claimed is:

1. The method of signal transmission consisting in generating at a transmitting point an alternating current wave of a given frequency varying in phase in accordance with signals to be transmitted, transmitting the generated waves over a signal transmission medium and at a receiving point producing from a portion of the received wave harmonics of said given frequency at least one of which is free from phase variations, selecting said one harmonic, producing from the selected harmonic a wave of a submultiple frequency equal to said given frequency and combining said submultiple frequency wave with another portion of the received varying phase wave to detect the phase variations therein corresponding to said signals to be transmitted.

2. A system of signaling between stations over a wave transmission medium, comprising at one station, a source transmitting an alternating current wave of a given frequency to said medium, and means to produce in the transmitted waves phase displacements proportional to signals to be transmitted, and at a receiving station, means to produce from a portion of the received wave, a harmonic thereof of constant phase, means to produce from said harmonic a wave of a submultiple frequency equal to said given frequency, means to combine said submultiple frequency wave with another portion of the received phase displaced wave of given frequency to detect the phase displacements therein and signaling means responsive to the detected phase displacements.

3. In a transmission system comprising a plurality of stations connected by a wave transmission medium, means at one station for generating and transmitting to said medium an alternating current wave of a given frequency varying in phase in accordance with indications to be transmitted, means at another station to produce from a portion of the received phase-varying wave of given frequency, harmonics of said given frequency, means to select from said harmonics one of constant phase, means to produce from the selected harmonic a constant phase wave of a submultiple frequency equal to said given frequency, means to modulate said submultiple frequency wave with another portion of said phase-varying wave of said given frequency to detect the phase variations therein, and indicating means responsive to the detected phase variations.

4. A system for signaling between stations connected by a wave transmission medium, comprising at one station, a source transmitting an alternating current wave of a given frequency to said medium and means to produce phase displacements proportional to signals to be transmitted in the transmitted wave, and at another station, means to receive the transmitted phase-displaced signal wave, means to modulate the received wave with another wave of the same frequency but of constant phase, derived from said received wave to detect the phase displacements therein, and a signaling device responsive to the detected phase displacements, the constant phase in the derived wave being attained by making the unit phase displacement per unit signal variation in the wave of said given fre-

quency transmitted to said medium at said one station equal to

$$\frac{2\pi}{n}$$

5 where n is any integer greater than 2, producing a wave of the harmonic frequency nf from the received phase-displaced wave at said other station, where f is said given frequency, and producing from said wave of harmonic frequency a
10 wave of the submultiple frequency f which will be of constant phase.

5. A system of signaling comprising a plurality of stations connected by a wave transmission medium, one station comprising a source
15 of varying signals, a source of alternating current waves of constant frequency f connected to said medium, means to shift the phase of the waves from said constant frequency source
20 transmitted over said medium progressively in

accordance with the varying signals from said signal source, the unit of phase shift per unit signal variation being equal to

$$\frac{2\pi}{n}$$

5 where n is any integer greater than 2, a receiving station comprising means for producing harmonics of the phase-shifted wave received over said medium, means to select a wave of the frequency nf from the produced harmonics, means
10 to produce submultiples of the selected harmonic frequency wave, means to select a wave of the submultiple frequency f from the resulting waves, means to modulate the received phase-shifted
15 waves with the selected wave of submultiple frequency f to detect the phase variations and means to reproduce the original signal variations from said phase variations.

WARREN A. MARRISON. 20