May 15, 1928. 1,669,450

S. BRAND

SYNCHRONIZATION IN MULTIPLEX SIGNALING

Filed May 1, 1926 2 Sheets-Sheet 1

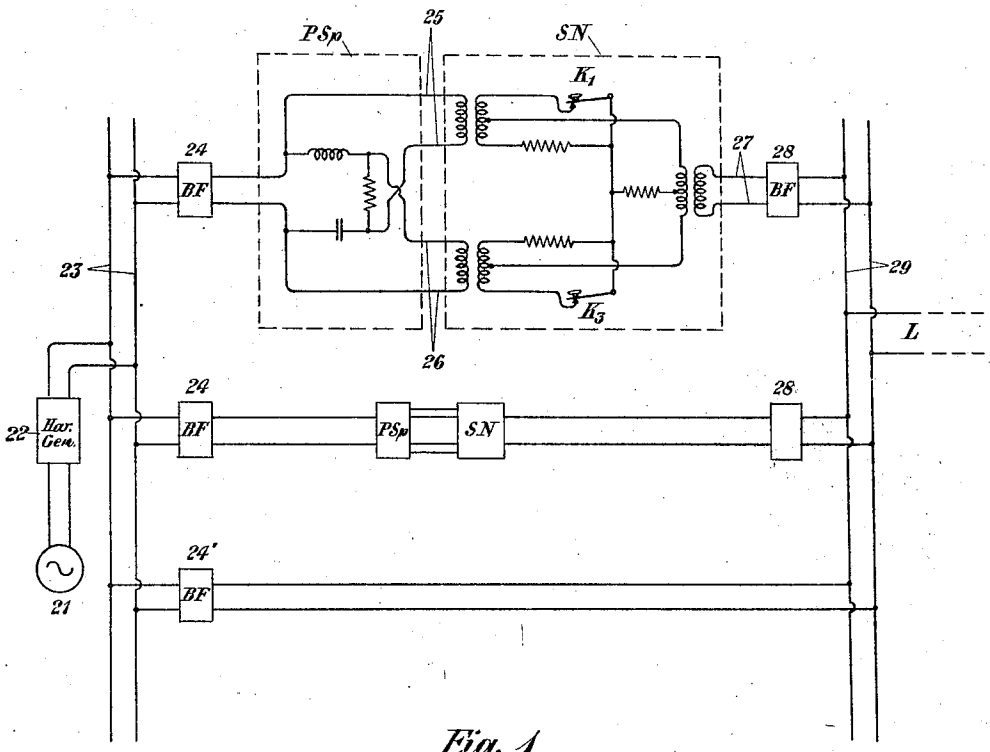


Fig. 1

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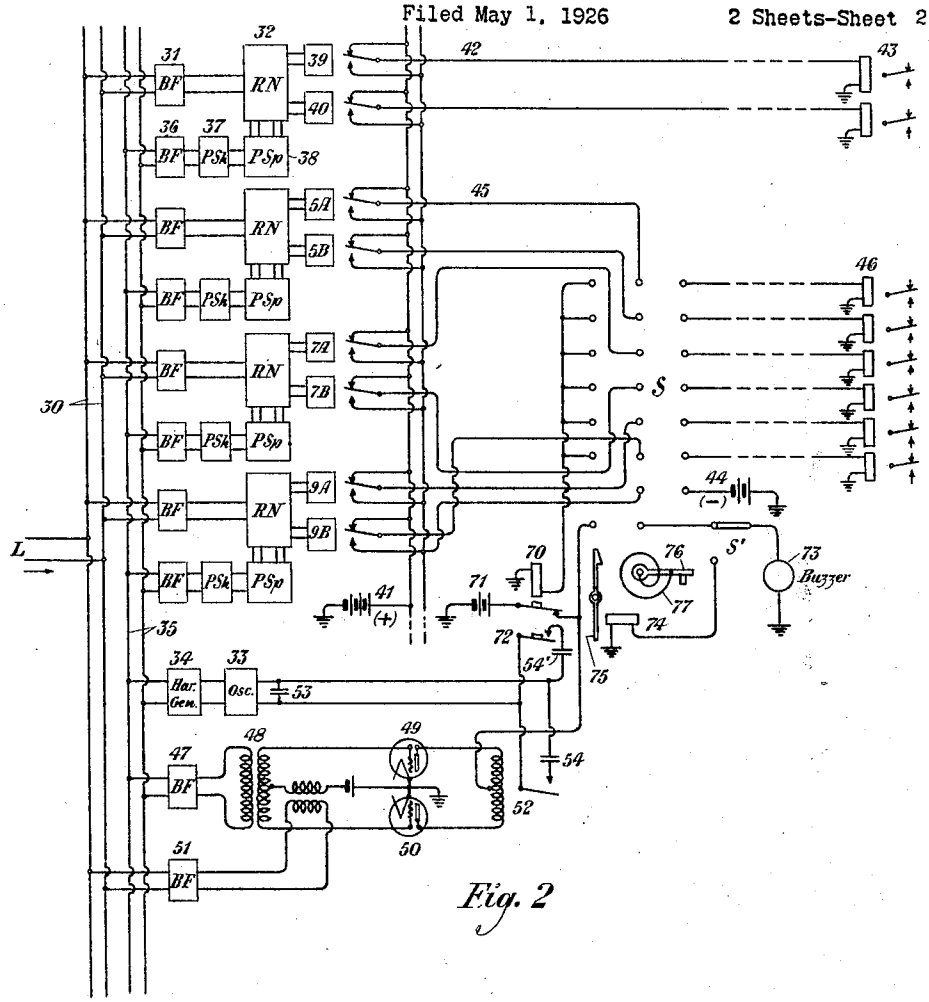


Fig. 2

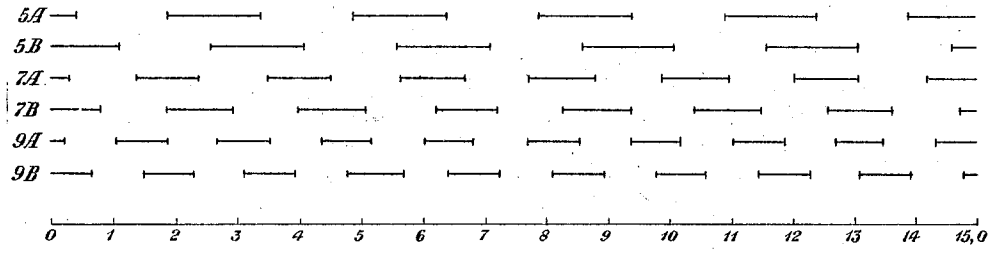


Fig. 3

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Patented May 15, 1928. 1,669,450

UNITED STATES PATENT OFFICE.

SMART BRAND, OF BROOKLYN, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

SYNCHRONIZATION IN MULTIPLEX SIGNALING.

Application filed May 1, 1926. Serial No. 106,099.

It is an object of my invention to provide a method and suitable apparatus for establishing and maintaining proper synchronism and phase relations in a multiplex carrier current signaling system. In a system in which, at the receiving end, there are locally generated currents each of the same frequency as respective received carrier current components, it is an object of my invention to establish and maintain synchronism and proper phase relation between each received carrier current component and the respective locally generated current of the same frequency. These objects of my invention, and other objects will become apparent on consideration of an example of procedure in accordance with the invention which I have chosen to disclose in this specification taken with the accompanying drawings. It will be understood that this specification relates largely to this particular example of the invention, and that the invention will be defined in the appended claims.

Referring to the drawings, Figure 1 is a diagram of transmitting apparatus that may be employed in practicing my invention. Fig. 2 is a diagram of corresponding receiving apparatus, and Fig. 3 is a diagram illustrating certain phase relations that will be referred to in explaining the principle involved in the operation of the system of Figs. 1 and 2.

At the sending end shown in Fig. 1, the generator 21 delivers an alternating current of a certain fundamental frequency to the harmonic generator 22 which may be arranged so that its output will comprise the said fundamental and odd harmonics thereof. For example, the fundamental frequency may be 85 cycles per second, and the odd harmonics would accordingly have frequencies of 85+170, 85+340, etc.

The superposed harmonic currents from the harmonic generator 22 go to the bus-bars 23 and thence, respectively, through the multiple band filters 24, each adapted to pass one and only one of the said harmonic currents. The current through one such band filter 24′ goes unmodified to the bus-bars 29 and thence to the line L. This current is for synchronizing at the receiving end, as will be explained presently. In connection with the numerical frequency values that have been suggested, this synchronizing current may conveniently be taken at the frequency of 1275 cycles per second.

The current through each of the other band filters 24 goes to a phase splitter PSp which delivers two currents of the input frequency 90° apart in phase over the respective conductor pairs 25 and 26. These two currents go over these conductor pairs to the sending network SN where each current component is controlled by a corresponding key K_1 or K_2. Each key operates when it is shifted to reverse the phase of the corresponding current component. These current components as controlled by the said keys are superposed in the conductors 27 leading to the band filter 28 through which they pass to the bus-bars 29 and the line L.

At the receiving station shown in Fig. 2, these superposed current components of various frequencies, each comprising two components 90° apart, each such component having its phase reversed from time to time by signaling changes, all come in on the line L and go thence to the bus-bars 30. The respective frequency bands are separated and pass through the respective band filters 31 to the corresponding receiving networks 32.

By means presently to be described, the oscillation generator 33 generates a fundamental current of the same frequency as for the generator 21 at the sending end. This current goes from the generator 33 to the harmonic generator 34 which may be made so that its output comprises the odd harmonics, all of which are put on the bus-bars 35. These harmonics are separated out and passed by the respective band filter 36, and from each such band filter 36 the corresponding current of a single frequency goes through the adjustable phase shifter 37 to the phase splitter 38 whose output consists of two currents of the same frequency, 90° apart in phase, which go to the receiving network RN or 32.

Each receiving network 32 controls two receiving relays such as 39 and 40. One relay 39 is affected by one component from the line, and changes between marking and spacing according as the current received from the line changes between being in phase with the current component from the phase splitter and being in phase opposition. Similarly, the other relay 40 is affected by the

other component of current from the line, and it operates only on changes between the phase agreement and phase opposition for the corresponding component of received current on the line and the locally generated current component.

These relays 39 and 40 control respective circuits 42 to signal receiving polarized relays 43. Normally, the multiple double throw switch S is thrown to the right so that one armature position for such a relay as 39 or 40 puts positive battery 41 on the line 42, and the other armature position puts negative battery 44 on the line 42.

The particular frequency appropriated for synchronizing that goes through the band filter 24′ at the sending end is received through the band filter 51 at the receiving end and goes to affect alike the grids of the two detectors 49 and 50.

Current of the same frequency from the local harmonic generator 34 is passed through the band filter 47 and applied through the transformer 48 to affect oppositely the grids of the two detectors 49 and 50.

When the two input electromotive forces from the respective filters 51 and 47 are 90° apart, the effect in the plate circuit relay 52 will be neutral, but any departure from the 90° relation will give an unbalanced effect in the plate circuit of the detectors 49 and 50 and shift the armature 52 one way or the other, accordingly.

The oscillation generator 33 has its usual tuned circuit comprising inductance and capacity, the normal capacity being represented by the condenser 53. This capacity is slightly less than the proper magnitude to put the oscillator 33 in synchronism with the generator 21 at the sending station. Accordingly, when the contacts controlled by the relay 52 are open, the oscillator 33 tends to speed up a little and causes a departure from the 90° relation between the input electromotive forces for the detectors 49 and 50. When the departure from the 90° relation becomes great enough, it causes the contacts of the relay 52 to close, thus putting the condenser 54 in parallel with the condenser 53 and slightly increasing the capacity of the tuned circuit of the oscillator 33. This increase of capacity is enough to make the oscillator slightly too slow. Accordingly, the oscillator slows down a little until the 90° reaction is restored for the input electromotive forces on the detectors 49 and 50, whereupon the contacts of relay 52 open again. Thus it will be seen that the oscillator 33 is held closely at the same frequency with the sending generator 21 and in definite phase relation therewith.

It has already been stated that the normal condition of the switch S is thrown to the right. It will be seen that from certain of the receiving network relays such as 5A and 5B, the conductors 45 to the signal relays 46 lead through respective arms of this switch S.

When the system is to be started up, it is necessary to have proper phase relation between each one of the received current components through respective filters such as 31, and each one of the locally generated current components taken off through respective filters such as 36. It will be seen that synchronism and phase agreement between the particular current components through the band filters 47 and 51 does not insure phase agreement for the other components nor for the fundamental of all the components. It is true that such phase agreement might be secured by adjustment of the various phase shifters 37, but on starting up the system after a shut down, it would be a tedious matter to adjust all these phase shifters. By my invention, it becomes possible, when starting up the system after a shut down, quickly to secure the desired synchronism and phase relation for all the current components for which adjustment of the phase shifters 37 will have been made in previous operation of the system.

Certain relays such as 39 and 40 are designated 5A, 5B, 7A, 7B, etc., as shown in Fig. 2. The numeral part, as 5 or 7, means the harmonic for the corresponding relay, as the fifth or seventh, and the letters A and B distinguish the two phases 90° apart.

To establish operation at proper synchronism and phase relation, the switch S is thrown over to the left, thus disconnecting certain of the signal indicating relays 46 and connecting in multiple to the relay 70 all the conductors 45 from the armature contacts of relays 5A, 5B, 7A, 7B, 9A and 9B.

By routine arrangement, the sending keys for both phases of the fifth, seventh and ninth harmonics are held closed at marking position. The switch S being thrown to the left takes battery 44 off the marking contacts of the relays 5A, 5B, etc., and connects buzzer 73 to an armature contact controlled by relay 70. As will be shown presently, the relays 5A, 5B, etc., will not all mark even though the corresponding keys at the sending end are held at marking, unless the phase relations are correct for all the components of the system; but when the phase relations are correct, these relays will all mark, provided the corresponding keys are held at marking. Assuming that these phase relations are not correct, then at least one of the armatures of the relays 5A, 5B, etc., will be on its upper or spacing contact, thus putting battery 41 on some such conductor as 45 and thence through the switch S to the relay 70. The relay 70, being energized, will cut off the battery 71 from the plate circuit of the detectors 49 and 50,

and will close the switch 72 across the contacts of condenser 54′, thus putting the condenser 54′ in parallel with condenser 53 and making the oscillator 33 operate a trifle slow. Accordingly, there will be a slow drift, the oscillator 33 lagging more and more relatively to the oscillator 21 at the sending end.

The diagram of Fig. 3 represents one complete cycle of phase shift between these two oscillators. At the zero position, they are supposed to be in the proper phase relation with all their harmonics in proper phase relation. At this zero position of relative phase shift between the generators of the current of fundamental frequency, all the receiving relays will be marking for which the corresponding sending keys are held in marking position. As the phase between the two generators shifts, the various relays will mark and space alternately. In one cycle of phase shift between the two generators, the relays on the fifth harmonic will mark and space five times, as represented by the horizontal line segments in the upper part of Fig. 3. That is, as the relative phase shift between the fundamentals progresses from zero, we read the diagram of Fig. 3 from left to right, and the top row of horizontal line segments shows by the lines when the relay 5A is marking, and by the intervening spaces when the said relay is spacing. For example, at four-fifteenths of a cycle of relative phase shift the relay 5A is spacing, but just before five-fifteenths of a cycle of relative phase shift, the relay 5A begins to mark. It is assumed that each relay marks half the time and spaces half the time. It may be sufficient if this condition is satisfied only approximately. It is a condition that may be secured by adjustment of the relays.

Similarly, for one cycle of relative phase shift between the fundamentals the relays 7A and 7B each mark and space seven times, and the relays 9A and 9B each mark and space nine times.

An inspection of Fig. 3 shows that only at zero relative phase shift are all the relays marking at the same time. For example, at five-fifteenths of a complete cycle of relative phase shift, relays 5A, 7B, 9A and 9B are marking, but 5B and 7A are spacing.

Accordingly, for any position of relative phase shift of the fundamentals except the zero position, some one at least of the relays 5A, 5B, etc., will be spacing, and the corresponding armature will be on its upper contact, thus holding battery 41 on relay 70. But when the relative phase shift has proceeded to the stage of a cycle corresponding to the abscissa 15 in Fig. 3, and all the relays 5A, 5B, etc., are marking, this opens the circuit from battery 41 to relay 70 which accordingly drops its armatures, thus removing the condenser 54′ from the tuning circuit of oscillator 33 and applying battery 71 to the plate circuit of the detectors 49 and 50, and to the circuit of buzzer 73. The relative phase shift then ceases and the apparatus keeps in synchronism. The operation of the buzzer notifies the attendant that the proper phase relation for the oscillator 33 has been reached, and he throws the switch S from left to right, thus connecting negative battery 44 to the marking contacts of the relays 39, 40, 5A, 5B, etc., and cutting off the buzzer 73 from battery 71. This leaves the system subject to normal control through the detectors 49 and 50, which serve to hold the oscillator 33 in the proper phase relation, as heretofore described.

By throwing the switch S′ from the position shown in Fig. 2, the switch S can be made to operate automatically. It will be seen that in this case instead of operating the buzzer 73, the magnet 74 is operated, which withdraws the dog 75 holding the end of the switch arm 76, and this permits the spring 77 to throw the switch arm 76 to the right.

I claim:

1. The method of bringing a set of harmonic currents respectively into synchronism with another set of such currents, which consists in causing a slowly increasing relative lag between the two sets of currents until a sufficient number of components of the two sets of currents are in phase and then initiating automatic regulation of one set of currents to hold them in phase with the currents of the other set by applying one current of one set to regulate the corresponding current of the other set.

2. The method of establishing phase agreement between each of a set of locally generated harmonic currents and each of a corresponding set of received harmonic currents, which consists in slowly shifting the phase of the locally generated currents relatively to the received currents until there is phase agreement between enough of the currents of the two sets respectively to necessitate phase agreement throughout, and then applying one of the received currents to regulate the corresponding locally generated current.

3. The method of initiating automatic synchronism of one set of harmonic currents with another set by interaction of one current of one set with the corresponding current of the other set, which consists in permitting one set to drift relatively in phase until there is phase agreement between enough of the currents of one set and the corresponding currents of the other set to establish proper phase relation throughout and then starting the automatic synchronizing apparatus in operation.

4. The method of bringing two sets of

harmonic alternating currents into respective phase agreement, which consists in indicating phase agreement and phase opposition for each pair of currents of the two sets and permitting a drift in phase between the two sets until phase agreement is indicated by a selected number of the pairs of currents sufficient to determine phase agreement throughout, and then initiating synchronous control of one set with the other by automatic interaction between a particular current of one set and the corresponding current of the other set.

5. In combination, in a multiplex carrier current receiving system in which the received currents are harmonics of one fundamental, local means to generate harmonic currents corresponding approximately in frequency with the respective received currents, respective relays each operated according to the phase agreement of a received current and the corresponding locally generated current, regulating means and means to initiate operation of said regulating means responsive to simultaneous operation of enough of the relays to determine phase agreement for all the currents.

6. In combination, in a multiplex carrier current receiving system in which the received currents are harmonics of one fundamental, local means to generate harmonic currents corresponding approximately in frequency with the respective received currents, respective relays each operated by conjoint action of a received current and the corresponding locally generated current, synchronizing means and means to initiate its action responsive to the simultaneous operation of enough of the relays to determine phase agreement for all the currents.

7. In combination, in a multiplex carrier current receiving system in which the received currents are harmonics of one fundamental, local means to generate harmonic currents corresponding approximately in frequency with the respective received currents, synchronizing means, and means to initiate the operation thereof, said last mentioned means controlled by the conjoint action of a plurality of the received currents and the corresponding locally generated currents.

8. In combination, in a multiplex carrier current receiving system in which the received currents are harmonics of one fundamental, local means to generate a set of harmonic currents corresponding approximately to said received currents, a regulator for maintaining synchronism among all the currents respectively when once it is established, respective means responsive according to the phase relation of the various currents and means operated thereby to indicate when the synchronizing apparatus should be started in operation.

In testimony whereof, I have signed my name to this specification this 29th day of April 1926.

SMART BRAND.