Oct. 16, 1934. 1,976,877

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SYNCHRONIZATION SYSTEM

Filed Nov. 13, 1931 2 Sheets-Sheet 1

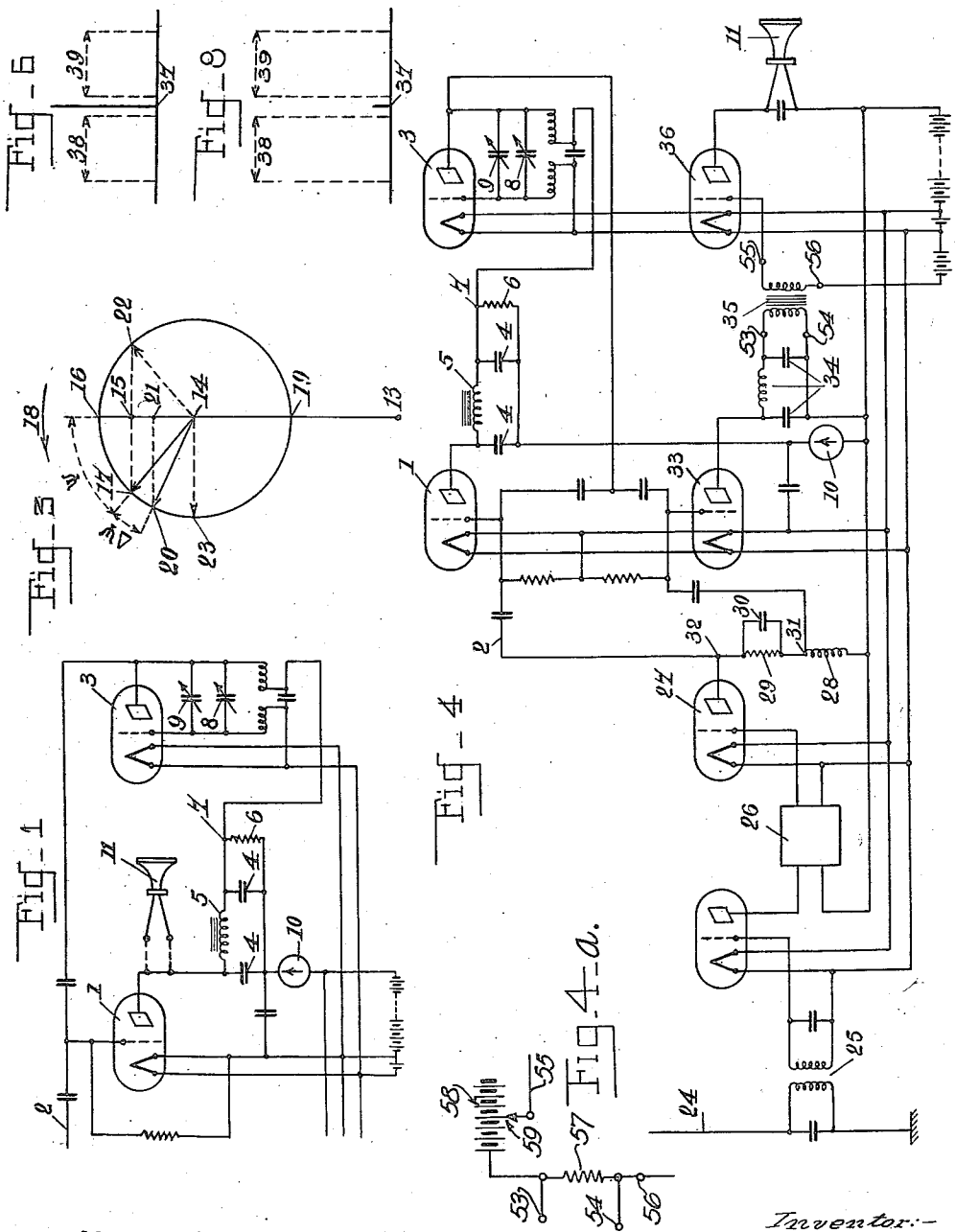


Fig. 1

Fig. 4

Fig. 4-a.

Fig. 5

Fig. 8

Fig. 3

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Fig. 2

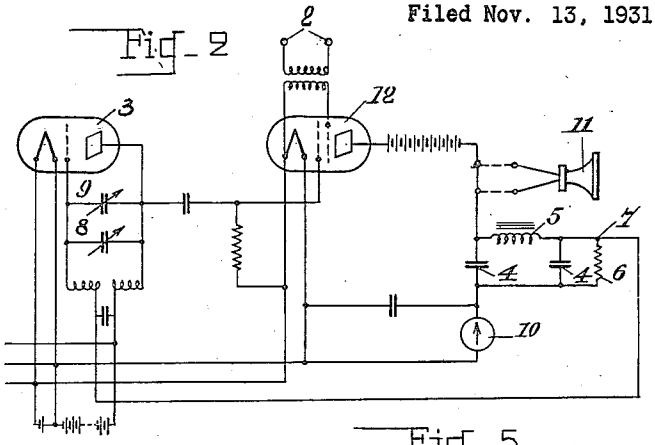


Fig. 10

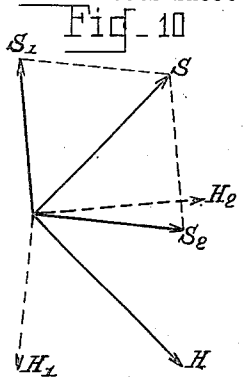


Fig. 5

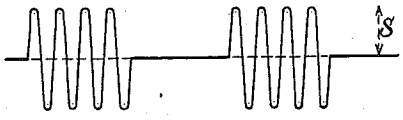


Fig. 9

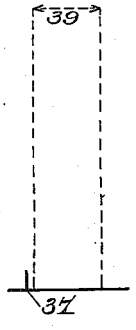


Fig. 7

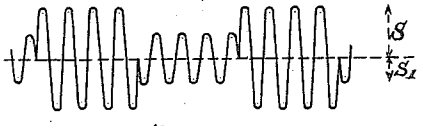
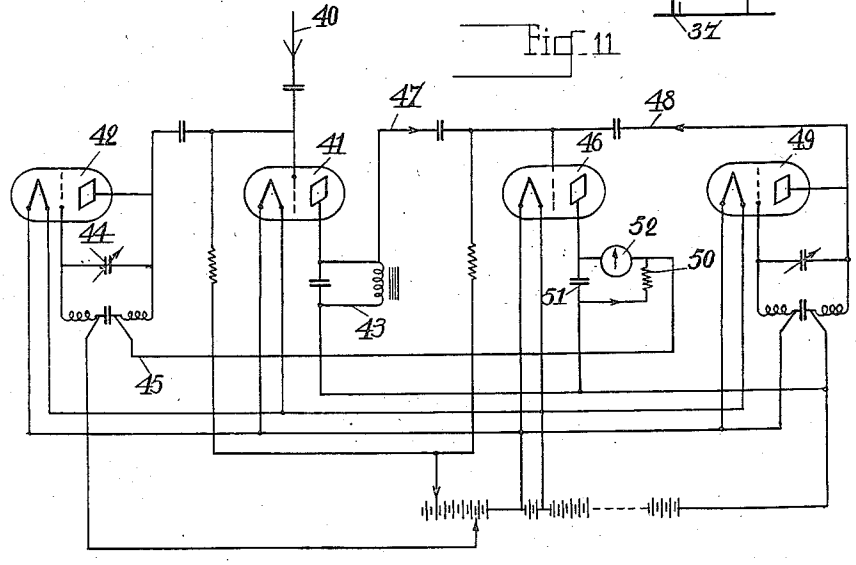


Fig. 11



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SYNCHRONIZATION SYSTEM

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Application November 13, 1931, Serial No. 574,858
In France November 19, 1930

19 Claims. (Cl. 250—8)

My invention relates broadly to high frequency oscillation systems and more particularly to an arrangement for obtaining locked synchronism, that is, a constant phase difference between two oscillations established by separate generators.

My invention relates chiefly to circuit arrangements in which the synchronizing arrangement is applied to a receiving system in which the controlling oscillation is produced by the received signal, and in which the oscillations from the local generator is combined with the receiver in order to assure an improved operation.

One of the objects of my invention is to provide a system for synchronizing the operation of a local source of oscillations with respect to a source of controlling oscillations for maintaining a constant phase difference between the controlling oscillations and the locally generated oscillations.

Another object of my invention is to provide a circuit arrangement for interconnecting a detector circuit arranged to receive signal oscillations with an oscillation generator circuit for establishing a selecting path for synchronizing current therebetween with means in the path for maintaining a constant phase difference between the locally generated oscillations and the controlling oscillations.

Still another object of my invention is to provide a circuit arrangement for a radio receiving system including a circuit for reproducing modulating signaling energy and a local generator of oscillations with a path therebetween constituted by a device having a suitable time constant for selecting a synchronizing current and maintaining a constant phase difference between the controlling oscillations and the locally generated oscillations.

Still another object of my invention is to provide a signal receiving circuit having a pair of branch circuits each including a detector in combination with a signal observing circuit and a local generator of oscillations with connections between said generator and one of said detectors for establishing a path for synchronizing current therebetween, and selective circuits interconnecting the other of said detectors with the signal observing circuit.

Still another important object of my invention is to provide in the phase difference control arrangement itself means to protect this arrangement from electromagnetic disturbances of every kind eventually received together with the controlling oscillation; said protection is quite necessary if the controlling oscillation proceeds from a wireless signal.

Other and further objects of my invention will be understood from the specification hereinafter following by reference to the accompanying drawings, in which:

Figure 1 diagrammatically illustrates a circuit arrangement of the synchronizing system of my invention; Fig. 2 shows a modified form of circuit embodying my invention; Fig. 3 is a theoretical diagram explaining the principles of my invention; Fig. 4 shows a homodyne receiver in which the synchronizing system of my invention is employed; Fig. 4a shows a modified form of coupling circuit for the second detector and the amplifying valve employed in the circuit of Fig. 4; Figs. 5, 6, 7, 8 and 9 are diagrams showing various types of signals which may be received employing the synchronizing system of my invention; Fig. 10 is a vector diagram showing the manner in which the receiving circuit of Fig. 4 operates to receive at the same time two signals having the same frequency but differing in phase; and Fig. 11 shows the circuit arrangement in the case of a receiving circuit for signal oscillations including a heterodyne generator.

The term "synchronism" herein is used to define the constant phase difference between a controlling oscillation and the locally generated oscillations. The controlling oscillation and one of the oscillations produced by the local generator are respectively represented by

$$S\sin(2\pi f\,t+\phi) \text{ and } H\sin(2\pi f_1 t+\phi_1)$$

My invention is directed to a system having circuit conditions in which the angular difference

$$\psi=(2\pi f_1 t+\phi_1)-(2\pi f\,t+\phi) \qquad (1)$$

will remain at all times as constant as possible. If an accidental cause temporarily affects this angular difference by an error of $\Delta\psi$, this error is automatically annulled before it attains a great value. The invention consists in the obtainment of this automatic correction by controlling the proper frequency of the local generator by a current whose value depends directly, and exclusively, upon the angular difference ψ.

For simplifying the explanation of the invention the angle ψ has been used to designate the difference of phase.

Fig. 1 shows the manner in which the local generator is placed in synchronism with the controlling oscillation. The grid of the detecting valve 1 is simultaneously affected by the con-

trolling oscillation, for instance a signal wave, which enters it from circuit 2, and by the oscillation of the local generator 3. These two oscillations, when superposed in the detector 1, will be mutually modulated. The plate circuit of the detecting valve thus carries on the one hand high-frequency currents and on the other hand a low-frequency current. The high-frequency currents are blocked by a low pass filter 4—5. The low-frequency current passes through a resistance 6 and becomes continuous when in synchronism, for $f=f_1$ where f is the frequency of the controlling oscillations and f_1 is the frequency of the locally generated oscillations. With certain types of signals, this latter condition requires a special construction of the filter 4—5, as will be described in detail hereinafter. The control of the local generator 3 is obtained by causing the frequency to this generator to depend upon the current (which is continuous when the circuits operate in synchronism) which passes through the resistance 6. This can be variously effected as for example by supplying the plate circuit of the generator 3 from the point 7, for it is a known fact that the frequency of such a generator will depend, to a small degree, but sufficient for the purpose of operation of the system of my invention, upon the potential at which its plate is supplied. To obtain the synchronism, that is, to place the generator 3 in step with the controlling oscillation received from circuit 2, it is simply necessary to properly tune the main condenser 8 and the auxiliary condenser 9, this being facilitated by the use of a telephone 11 connected at a suitable point of the circuit of detector valve 1, for observing the beats due to the interference of the two oscillations. As the resonance point is approached when regulating the condensers 8 and 9, the musical note produced by the beats becomes proportionally lower in pitch, and the note is no longer heard when the two oscillations are in synchronism, in which case the indicator on the milliammeter 10 will suddenly come to a position of rest. The synchronism is more stable when the current shown by the milliammeter 10 returns to the value observed before the signal is received from circuit 2. Under this condition, the two oscillations exciting the grid of the valve 1 will now be in quadrature. This adjustment is effected by slowly regulating the auxiliary condenser 9 until the pointer of the milliammeter 10 returns to the initial position.

As shown in Fig. 2, the modulation of the controlling oscillation received from circuit 2, by the oscillation of the local generator 3, may be effected in a double grid valve 12 one grid of this valve being actuated by the controlling oscillation and the other one by the local oscillation. In this modified arrangement, the frequency of the generator 3 is controlled in the manner described in Fig. 1 by supplying its grid from the point 7 in the filter circuit 4, 5 and 6.

The synchronizing system of my invention will be understood by reference to Fig. 3. The process for the synchronism is as follows (Fig. 3): The modulation of the controlling oscillation and the locally generated oscillation produces in the plate circuit of the valves 1 or 12, firstly, high frequency currents which are blocked by the filter 4—5, and secondly, a low-frequency current having the form

$$J=J_0+kS\cos\psi \qquad (2)$$

in which J_0 represents the permanent current indicated by the milliammeter 10 before the signal wave is produced at 2 and $kS\cos\psi$ is the detected current produced by the controlling oscillation; k is a constant depending chiefly upon the characteristics of the detecting valve; S is the amplitude of the controlling oscillation, for instance, the carrier wave of the signal; ψ the angular difference shown by the equation (1). The current J, which serves to maintain the synchronism of the generator 3, may be termed the "synchronizing current". This current can be represented by a segment 13—15 in Fig. 3, which is the sum of a segment 13—14 representing the permanent current J_0 and a segment 14—15 which is the projection, upon a fixed sector 14—16, of a vector 14—17 whose length is kS and which makes the angle ψ with the preceding. According to the definition of this angle (Equation 1) and in conformity to the graphic representation of sinusoidal currents, the vector 14—17 will turn with reference to the fixed vector 14—16 with an angular speed of $2\pi(f_1-f)$. The conventional direction adopted for this rotation is for instance shown by the arrow 18 when the frequency f_1 of the local generator exceeds the frequency f of the controlling oscillation. Since the frequency f_1 of the generator depends upon the potential of the point 7 in the filter system and hence upon the synchronizing current, two consequences will result: firstly, each value of this current situated between the limits 13—19 and 13—16 requires a certain adjustment C of the tuning condensers 8—9 in order that the frequency f_1 of the generator 3 will be exactly equal to the frequency f of the controlling oscillation; for one of these adjustments the current J for which $f=f_1$ is for instance the one represented by the segment 13—15. Secondly, if from any accidental cause the synchronizing current is modified, and hence the potential of the point 7 changed, the frequency of the generator will differ slightly from that of the signal, and the vector 14—17 will turn with reference to the fixed vector 14—16. Let it be supposed for instance that when the synchronizing current is reduced, this will diminish the frequency f_1, and inversely. Under these conditions, if the corresponding vector is momentarily in the position 14—20 corresponding to a setting $(\psi+\Delta\psi)$ erroneous of $\Delta\psi$, the synchronizing current represented by the segment 13—21 will be too small, so that the frequency f_1 of the generator becomes less than that of the signal. The vector 14—20 now automatically turns in the contrary direction to the arrow 18, and it returns to the proper position 14—17. When repeated for any other difference $\Delta\psi$, this reasoning leads to the same result, and shows that the position 14—17 is a position of stable equilibrium for the aforesaid adjustment C of the condensers 8—9. The synchronism is thus automatically maintained, as by definition, the vectors 14—16 and 14—17 representing the two oscillations will maintain a constant relative position. This synchronism is more stable when the tuning condensers 8—9 are given the particular capacity C_0 for which the synchronizing current J is equal to the permanent current J_0 as shown by the milliammeter 10 before producing the signal wave at 2. By means of this adjustment of the condensers, the two oscillations are in quadrature

$$\psi=\frac{\pi}{2},$$

and the vector 14—17 has the particular posi-

tion 14—23. It is evident that for this adjustment, a small error such as $\Delta\psi$ will cause the greatest variation of the synchronizing current, and hence the most powerful correction. If on the contrary to what has been arbitrarily supposed, a reduction of the synchronizing current occasioned an increase of the frequency f_1 of the generator, the practical result would be the same, and all of the above considerations as to the representative vector 14—17 would now apply to the symmetrical vector 14—22. These remarks justify the preceding assertions, namely, that in order to afford synchronism between the local generator and the signal, it is simply necessary to bring the condensers 8—9 into the immediate vicinity of the tuning, or more precisely, between the two values C_1 and C_2 corresponding respectively to the limits 13—16 and 13—19 which the synchronizing current J may assume. These limits are the extreme amplitudes of the beats shown by the milliammeter 10. When this synchronism has been thus obtained, it is made more stable by operating the auxiliary condenser 9 until the milliammeter 10 shows the same current J_0 as in the absence of the signal wave. Then the normal phase difference is

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

and the variations in the amplitude of synchronizing current J are directly proportional to the small variations in said phase difference.

Fig. 4 shows the application of the synchronizing system of my invention to a signal receiving system. This signal, when collected by the antenna or a line wire circuit 24, first passes through the usual devices, such as the resonators 25 and an amplifier 26. The frequency may be changed, if desired, by heterodynes (not shown) and the energy supplied to the input circuit of valve 27. The plate circuit of the valve 27 comprises an inductance 28 and a resistance 29, shunted by a small capacity 30; these three elements are permanently adjusted so that the controlling oscillation will have at the point 32 in the output circuit of valve 27 a phase in quadrature with the one which it had at the point 31. By a suitable choice of resistance 29 and coil 28, the amplitude of the signal wave at point 32 is made several times larger than the amplitude at point 31. The point 32 is connected to the circuit 2 of the detector valve 1 described in Fig. 1. The condensers 8—9 are carefully adjusted so that the controlling oscillation and the local oscillation which interfere in the valve 1 will be practically in quadrature, this result being obtained when the current in the milliammeter 10 gives the same reading as the reading it indicated before the receiver was tuned to the signal wave. A second detector valve 33 is provided for the recording of the signal or for the operation of the telephone 11 through amplifier 36. According to the preceding arrangements, the signal wave and the local oscillations from oscillator tube 3 will now be mutually modulated in phase, and thus the plate circuit carries a current which is an exact reproduction of the telephone signals or of the dots and dashes produced by the telegraph key at the transmitting station. A filter 34 arranged for the proper range of frequency, such as a frequency of 4000 in the case of telephony, transmits this current to the transformer 35 and to the amplifying valve 36 supplying the telephone 11. Since the amplification at the point 32 is several times greater than that of the point 31, the detector valve 1 will assure the synchronism as long as the fading does not cause the disappearance of the reception itself which is assured by the second detector valve 33. An automatic corrector for the fading may be connected in the plate circuit of the valve 33, and it is controlled by the mean current supplied by modulating the local oscillation by the carrier oscillation. If the receiving is of a telegraphic nature, the transformer 35 will be replaced by suitable interconnecting means, for instance the resistance 57 and the biasing source shown in Fig. 4*a*. I have shown the modified coupling arrangement of Fig. 4*a* connected between the second detector valve 33 and the amplifying valve 36 between terminal points 53, 54, 55 and 56 indicated in Fig. 4. The transformer 35 is eliminated and resistance 57 connected in lieu thereof between terminals 53 and 54. The battery 58 with adjustable tap 59 thereon is connected with the grid of amplifying valve 36 through terminal 55 as shown. With this circuit connection the receiver may be used in telegraphic reception.

In the simplified receivers, such as those used for radio broadcasting reception, the filter 4, 5, 6, may be replaced by a condenser 4, in parallel with the resistance 6; such an arrangement will be illustrated in 50, 51, Fig. 11. The principal advantage of the present method is that it comprises, in the interior of the synchronizing device, a means of selection considerably more effective than any filter or resonator which might be placed externally to the said device. The said selection protects the synchronism against the strongest atmospherics, and against the action of side oscillations even when their frequencies are very close to the carrier frequency. This result has never yet been obtained; it is indispensable in order to synchronize a locally generated oscillation on a radio wave pertaining to a signal.

The said selection is based entirely on the fact that by combination with the locally generated oscillation, the controlling oscillation $S \sin (2\pi ft+\epsilon)$ is linearly transformed in the detector into a current of the same form $kS \cos \psi$. It can be likewise proved that if such a transformation is correctly realized for the controlling oscillation, it will necessarily be so for all other received oscillations. Under these conditions, the controlling oscillation, synchronized on the locally generated oscillation, is transformed into a current the frequency of which is null; in the same way, the side oscillations of the same signal are transformed linearly into low frequency sinusoidal currents; the oscillations due to the statics varying at random are transformed into currents whose intensities have the same probability of being positive or negative. Such a method of transformation is well known, since it is used each time that the frequency of a signal is lowered in a superheterodyne receiver; the means permitting the exact realization of the said linear transformation are also well known, and I have already published two demonstrations thereof; one applied to the ordinary detector of Fig. 1, and the other to the bi-grid detector of Fig. 2. But it is the first time that the said transformation has been used to render the frequency of a received oscillation null, in order to allow it, after selection, to synchronize a locally generated oscillation.

Given the said linear transformation as it is resumed by the Formula (2) and explained by Fig. 3, the selection of the synchronizing current $kS \cos \psi$ produced by the detection of the con-

trolling oscillation is now evident; in fact the said current may be isolated by a low-pass filter 4, 5, 6 (Figs. 1 and 2), since its frequency is null; whereas the frequencies of the undesired currents produced by the detection of interfering waves are not null. An excellent selection can also be obtained by the simple aperiodic circuit 50, 51 (Fig. 11); it can be proved that in combination with the homodyne reception of an oscillation, such an aperiodic circuit placed in the output of the detector protects the current whose frequency is null, deduced from the said oscillation, exactly in the same way as in principle it could be protected by a resonator having the same time constant as the said circuit, but which would be tuned on the frequency f of the oscillation and placed in the input of the detector. In fact, the continuous synchronizing current $kS \cos \psi$ entirely passes through resistance 50, whereas the undesired currents, negative or positive at random, caused by the combination of the atmospherics with the locally generated oscillation, produce in condenser 51 in accumulative effect inversely proportional to the square root of the time constant of circuit 50, 51; consequently the protection insured to the synchronizing current is proportional to the said square root.

The advantage of selecting the controlling oscillation after its frequency is annulled results from the fact that it is possible to construct very easily a low-pass filter having an extremely narrow band, or an aperiodic circuit having a very large time constant. Consequently, the present method allows in principle to increase so far as it is necessary the selection of the synchronizing current—i. e. the protection of synchronism from statics and interfering waves.

In practice, the minimum value that can be given to the band of the low-pass filter, or the maximum value of the time constant of the aperiodic circuit, are only limited by the stability of the carrier frequency or pilot on which the locally generated oscillation is to be synchronized. The said frequency always varies slightly, these variations being due for instance to the propagation through the ether. If the maximum rate of the variations affecting f is Δf, i. e. if the said rate represents a variation of Δf cycles in one second, then the extent of the band of the circuit 4, 5, 6 or 50, 51, must be at least equal to Δf, and its time constant at most to

$$\frac{1}{2\pi.\Delta f}.$$

Such a band proceeds from zero to about thirty cycles for the very short waves.

As a consequence of the excellent selection insured by the low-pass filter or by the aperiodic filter, the influence of the statics and interfering waves is completely eliminated, even when in the transmitting station the amplitude of the carrier wave or pilot, destined to control the locally generated oscillation of the receiver, is systematically weakened in regard to the side band oscillations of the same signal.

The main feature of the present invention, now clearly stated by the preceding explanations, may be summarized as follows: the said invention concerns systems whose object is to maintain a substantially constant phase difference between a local oscillation and a controlling oscillation, i. e., those systems where the frequency of one of the said oscillations is automatically controlled by a variable physical quantity depending from the said phase difference; this variable physical quantity may be a current, a difference of potential, or more generally, any physical quantity resulting directly or indirectly from the interference of the two oscillations and capable of controlling the frequency of any one of them. The object of the invention is to protect the synchronism against the interfering waves, side waves, statics, which may be received together with the controlling oscillation. To do this, the whole of the received oscillations is combined with the locally generated oscillation in an instrumentality whose characteristic is curved, such as a detector. This combination is managed in such a way that each of the said received oscillations exclusively produces (in addition to the high frequency terms which are easily eliminated) a variable physical quantity whose amplitude is as exactly as possible proportional to the amplitude of the said received oscillation, and whose phase is equal to the difference between the phase of the said oscillation and the phase of the locally generated oscillation. The difference of phase between the locally generated oscillations and the controlling oscillation being practically constant, the variable physical quantity, which results from the said controlling oscillation, alone has a zero frequency, i. e., is not oscillatory. All the other variable physical quantities produced by the interfering waves are sinusoids whose frequencies are not null. If thus, between the detector from which the whole of said physical quantities are issued, and the local generator whose frequency is controlled by that physical quantity which corresponds to the controlling oscillation, a device is placed which is selectively responsive only to non-oscillatory and very low frequency variations of the said physical quantity, the synchronism will be sufficiently protected from all interferences.

The present process, therefore, permits the synchronization of a locally generated oscillation on a controlling oscillation belonging to a signal of any type whatever. The said controlling oscillation may be the carrier wave or pilot 37 of a telephonic signal comprising one or two bands 38, 39, this carrier wave having either a normal (Fig. 6) or a weakened amplitude (Figs. 8 and 9); or even the wave of a telegraphic signal transmitted by means of either marking waves (Fig. 5) or marking waves and spacing waves (Fig. 7) having unequal amplitudes. It is known that these two types of telegraphic signals are equal to side oscillations accompanying a carrier wave, whose amplitude is variable but preserves always the same sign. In the present process of synchronization, the variations in the amplitude of the carrier wave have no effect whatever on the stability of the synchronism, since the latter is regulated so as to place the locally generated oscillation in quadrature on the controlling oscillation.

The synchronized arrangement further provides for the simultaneous reception of two signals whose carrying oscillations have the same frequency but differ in phase. The said signals may be of the type comprising a carrier and symmetrical bands, as shown in Figs. 6 and 8. The two carriers of same frequency as shown by the vectors S_1 S_2 in Fig. 10 are in fact equivalent to a single oscillation represented by the resulting vector S and they are thus enabled to synchronize the local generator, as above stated. The local oscillation H produced by this generator is sent through two phase-varying devices, and said oscillation is thus converted into two auxiliary oscillations H_1 H_2 which are re-

spectively in quadrature with the signal oscillations S_1 S_2. Herein the auxiliary oscillation H_1 will serve to receive the signal S_1 and to eliminate the signal S_2, and inversely for the auxiliary oscillation H_2.

The signal sent out by the transmitting station may further have the form:

$$S[1+\sin(2\pi Ft+\Phi)]\sin(2\pi ft+\epsilon) \qquad (3)$$

and thus it will comprise a carrier whose frequency is f and whose amplitude is modulated with another frequency F. The receiver may comprise any suitable arrangement as shown for example in Fig. 4, in which the carrier is modulated in the valve 33 by a local oscillation $H\sin(2\pi ft+\phi)$, and thus the current from the transformer 35 has the form:

$$S\sin(2\pi Ft+\Phi$$

and the output end of this transformer may serve as the starting point of a second arrangement which is the same as the one first mentioned but in which the local generator is synchronized with the frequency F.

By means of the signals specified in Equation (3) it is further possible to receive the carrier whose frequency is f, to amplify and to select such oscillation in filters whose band is comprised between the frequencies $f+F$ and $f-F$; and then to detect such oscillation by means of an ordinary detector. The detected current, whose frequency is F, is then received by a device which is synchronized with this frequency. This method will prove advantageous when the frequency f of the carrier is too unstable to allow it to synchronize a local generator.

The synchronized local generator may be the master oscillator of a transmitting station, and the controlling current is supplied by a small auxiliary generator or by the signal waves from another transmitting station.

For the reception of signals, this synchronized arrangement has numerous advantages which have already been shown by theoretical examination. The syntonic action is improved, as the filters such as 34, which are very readily constructed, will multiply the selection obtained in the high-frequency circuits by the selection obtained in the low-frequency circuits of the receiver.

The detection is made linear, and this improves the reproduction of words and music, and greatly reduces the drawbacks of fading.

The intensity of the aperiodic disturbances is much reduced with reference to the intensity of the signal. In the first place, the modulation by a powerful local oscillation eliminates the sets of disturbing waves whose phase, at the input end of the valve 33, is in quadrature with the phase of this local oscillation and thus the number of the disturbances is reduced to one-half, on the average, and the resulting improvement is substantially the same as if the power of the transmitting station were doubled. In the second place, the signals such as those represented in Figs. 7, 8, and 9 allow the use of almost the whole of the transmitted power for the lateral oscillations which form the signals themselves, instead of expending this power to no avail in the oscillation carrying the signals. The advantage thus obtained is the same as if the transmitted power were multiplied by a number between 3 and 4. In the third place, by reducing by one-half the width of the band occupied by the signal as represented in Fig. 9, and hence at the same time the width of the band of the receiving filter 34, the number of disturbances is again divided by two. Expressed as transmitted power, the total gain thus realized will consequently vary, according to the types of signals, between 2 and 14, approximately. During fading effects, the actual gain is still greater, as the improvements made in the detector operation which are due to the local oscillation will afford a greater benefit to the signal than to the disturbances which have a greater intensity.

The signals represented in Figs. 7 and 8 are to a certain degree secret and out of reach of unauthorized reception, since their reception requires an exactly synchronous local oscillation. Such signals cannot be received by an ordinary receiver as may be accomplished with the signals shown in Figs. 5 and 6, nor like the signals shown in Fig. 9 which may be picked up by use of a simple local generator whose frequency is approximately the same as that of the signal.

In Fig. 11, the oscillation enters at 40, where it has a certain frequency f_0; it interferes in a first detecting valve 41 with the oscillation furnished by a heterodyne generator 42 whose proper frequency is $(f_1)_0$. In the circuits such as 43 which are supplied by the detector 41, the new frequency f acquired by the controlling oscillation $S\sin(2\pi ft+\phi)$ is thus equal to the difference $(f_1)_0-f_0$ or to the sum $(f_1)_0+f_0$; in all cases, it depends upon the proper frequency $(f_1)_0$ of the heterodyne generator 42. This frequency $(f_1)_0$ will in turn depend on the one hand upon the tuning of the condenser 44, and on the other hand upon the characteristics of the generator, for instance, upon the potential of the conductor 45 supplying its plate. In consequence, by modifying this potential, one will thus modify the frequency f of the control oscillation in the circuits following the detector 41. In like manner, as in Fig. 1, another detector 46 is operated simultaneously at 47 by the control oscillation and at 48 by the local oscillation whose new frequency is f, and at 48 by a local oscillation supplied by the synchronous generator 49. Due to the interference occurring in the detector 46, the resistance 50 which is protected by a low pass filter or by a condenser 51, carries a synchronizing current which can be read on the milliammeter 52 and is represented by the Equation (2).

In this manner, any change in the angle ψ will change the current J as well as the drop of potential due to the flow of this current in the resistance 50. These changes of potential act upon the frequency $(f_1)_0$ of the heterodyne 42, and through the latter upon the frequency f of the control oscillation. This result can be obtained by supplying the plate circuit of the heterodyne 42 by the conductor 45 connected at the top of the resistance 50. In these conditions, the controlling frequency f is made to depend upon the angle ψ, and the synchronism is automatically maintained, as disclosed with reference to Fig. 1.

While I have described the synchronizing system of my invention in certain of its preferred embodiments, I desire that it be understood that modifications may be made and that no limitations upon my invention are intended other than are imposed by the scope of the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States is as follows:

1. In a phase difference control system, a signal receiving circuit, a source of local oscillations,

a pair of detector circuits connected therewith and operative upon the receipt of incoming signal oscillation, a signal observing device, selective means interconnecting said signal observing device with one of said detectors, an interconnecting path between said local source and the other of said detectors, and a plurality of impedance elements in said path for selecting a synchronizing current, means in the output of said path responsive to variations in said synchronizing current to maintain the normal phase difference between the locally generated oscillations and the incoming signal oscillations.

2. A phase difference control system comprising a circuit for controlling oscillation, a circuit for generating a local oscillation, an electron tube detector connected with said circuits, in which detector, the controlling oscillation is combined with the local oscillation so as to produce a detected current utilized as a synchronizing current, a low pass filter in the output of said electron tube detector to select said synchronizing current, and means causing said selected current to act upon the frequency of the local oscillation.

3. A phase difference control arrangement utilized as a homodyne receiver, comprising in combination a circuit for a controlling oscillation proceeding from signal waves, a local generator; a first detector in which the controlling oscillation is combined with an oscillation produced by the local generator, a low pass circuit selecting the detected current, continuous at synchronism, produced by the controlling oscillation, the band width of this low pass circuit being in accordance with the stability of the said controlling oscillation, and means whereby the said selected detected current controls the frequency of one of the two oscillations combined in the first detector to maintain these oscillations in locked synchronism and approximately in quadrature, a phase shifter whereby the controlling oscillation and the local oscillation now synchronous are brought into phase consonance, a second detector in which these oscillations in phase consonance are combined, a low pass circuit in the output of the second detector, a band width of this circuit being in accordance with the signal frequencies, such as audio frequency, and an indicator actuated by the signal.

4. In a receiving circuit for signal oscillations including a local heterodyne generator, a first detector simultaneously actuated by the signal and by said heterodyne generator in such manner that said detector will supply a control oscillation whose frequency is due to the superposition of the frequency of the signal and the frequency of the heterodyne, a local generator of synchronous oscillations, a second detector simultaneously actuated by said control oscillation and by said synchronous generator, a circuit interconnecting the second detector with said local heterodyne generator and providing a selecting path for synchronizing current whose amplitude is determined by the difference of phase between the control oscillation and the oscillation produced by said local synchronous generator, to maintain constant this difference of phase.

5. The method of equalizing the frequencies and controlling the phase difference of two sinusoidal oscillations, the amplitudes of either or both of which may be variable, which comprises combining the two sinusoidal oscillations to produce a variable physical entity which is substantially a sinusoidal function of the said phase difference, selecting this physical entity and utilizing this selected entity to maintain a normal phase difference between the two oscillations.

6. A system for maintaining two oscillations in locked synchronism, which comprises, a detector in which these oscillations coact, so as to transform one of these oscillations into a detected current approximately proportional to the projection of the vector representing the said oscillation upon the vector representing the other oscillation, a device selectively responsive to the action of this detected current, continuous at synchronism, and means whereby the response of said device controls the frequency of one of said oscillations.

7. A method of maintaining a locally generated oscillation in locked synchronism with a received oscillation which may be accompanied by other received oscillations, such as side band oscillations and disturbing oscillations, which comprises combining through a linear detection the locally generated oscillation with the whole of the received oscillations, in such a way that the amplitude of the detected current produced in any one of these received oscillations is approximately proportional to the projection of the vector representing the said received oscillation upon the vector representing the locally generated oscillation, selecting the detected current produced by the received oscillation which is to be maintained in locked synchronism with the locally generated oscillation, and utilizing the said selected current to control the frequency of one of the two said synchronized oscillations.

8. A system for maintaining two oscillations in locked synchronism comprising a device in which the oscillations coact, means whereby this coaction transformers one of the said oscillations into a current whose amplitude is approximately proportional to the projection of the vector representing this oscillation upon the vector representing the other oscillation, this amplitude being approximately constant when the locked synchronism is obtained, means selectively responsive to the action of the said current, and means whereby said response controls the frequency of one of said oscillations.

9. A system for maintaining in locked synchronism two oscillations, comprising an electron tube detector in which the two oscillations are mutually modulated, means whereby this mutual modulation transforms one of the said oscillations into a detected current whose amplitude is approximately proportional to the projection of the vector representing this oscillation upon the vector representing the other oscillation, a circuit constituting a path for continuous and low frequency currents, for selecting the said detected current, and means in the output of said circuit whereby the selected current controls the frequency of one of said oscillations to maintain the two oscillations in locked synchronism.

10. A system for maintaining in locked synchronism two oscillations, the proper frequencies of either or both of which may admit slight variations, comprising a detector in which the two oscillations coact, means whereby this coaction transforms one of the said oscillations into a detected current whose amplitude is approximately proportional to the projection of the vector representing this oscillation upon the vector representing the other oscillation, a circuit constituting a selecting path for said detected current, the width of the band of this

current extending from zero to a value in accordance with the said variations of frequencies, and means in the output of said circuit whereby the selected detected current controls the frequency of one of said oscillations.

11. A system for maintaining two oscillations approximately in quadrature, the proper frequencies of which may be slightly variable, comprising a local generator acting on the frequency of one of said oscillations, a detector in which these oscillations are mutually modulated, means whereby the amplitude of the detected current thus produced in the output of the detector by one of the said oscillations is approximately proportional to the small changes in the phase difference of the two oscillations with respect to the quadrature, a resistance in parallel with a condenser in the output of the detector, the time constant of said resistance condenser being in accordance with the rate of the said small changes in the phase difference, and a connection leading from a point adjacent said resistance to said local generator, said connection acting on the frequency of the local generator to maintain the two oscillations approximately in quadrature.

12. A system for maintaining approximately in quadrature a locally generated oscillation and a received oscillation proceeding from a Hertzian wave whose frequency admits slight variations, comprising in combination a detector on which the two said oscillations coact, means whereby the amplitude of the detected current thus produced by the received oscillation is approximately proportional to the small changes in the phase difference of said oscillations with respect to the quadrature, a circuit in the output of said detector consitituting a path for said detected current exclusively, the time constant of this circuit being in accordance to the rate of the variations in the frequency of the Hertzian wave, and means in the output of said circuit responsive to the variations in the amplitude of said detected current, to control the phase difference of said oscillations.

13. A system for maintaining a locally generated oscillation in locked synchronism with a received controlling oscillation, which may be accompanied by other received oscillations, such as side bands oscillations and disturbing oscillations, which comprises, a detector in which the locally generated oscillation coact with the whole of the received oscillations, means whereby this coaction transforms each received oscillation into a detected current whose amplitude is approximately proportional to the amplitude of the said received oscillation, and whose phase is equal to the difference between the phase of said received oscillation and the phase of the local oscillation, a device selectively responsive to the action of the detected current produced by the controlling oscillation, and means whereby the response of said device controls the phase difference between the two said synchronized oscillations.

14. A phase difference control arrangement to receive a signal produced by modulating a carrier wave, comprising a local generator generating an auxiliary oscillation, a detector on which the signal waves and the auxiliary oscillation coact so as to transform the carrier wave into a detected current the amplitude of which is approximately proportional to the projection of the vector representing said carrier wave upon the vector representing the auxiliary oscillation, a circuit in the output of said detector to select continuous current, means in the output of said selective circuit controlling the frequency of the local generator, and receiving means in the output of the detector.

15. A method of maintaining locked synchronism, i. e. with substantially constant phase difference, between two electromagnetic oscillations which may be accompanied by side-band and disturbing oscillations, which comprises combining the two first named or synchronous oscillations in a detecting device for the production of a variable physical quantity, whose magnitude is approximately proportional to the projection of the one on the other of the vectors representative of the two synchronous oscillations, said magnitude becoming substantially constant on the attainment of locked synchronism; causing said physical quantity to act on a device selectively responsive only to non-oscillatory and very low frequency variations of said physical quantity and utilizing the result of its action on said selectively responsive device to control the frequency of one of the synchronous oscillations.

16. A phase difference control arrangement for the homodyne reception of a telegraphic signal constituted by marking waves and spaces, which comprises a local source generating a local wave of constant amplitude and of the same frequency as the said marking waves, a detector in which each marking wave is combined with the local wave and transformed by this combination into a direct impulse whose intensity is varying as the cosinus of the phase difference between the two said waves, a device having a high time constant in which the discontinuous succession of said impulses produces an undulating current whose sign is positive or negative along with the said cosinus, means under the control of said undulating current to maintain in quadrature the local wave and the signal waves interfering in the detector, and a phase shifter restoring the convenient phase difference of said waves for the homodyne reception of the signal.

17. A phase difference control arrangement for the homodyne reception of a telegraphic signal constituted by marking and spacing waves whose phases are opposite and amplitudes unequal, which comprises a local source generating a local wave of constant phase and amplitude and of the same frequency as the said signal waves, a detector in which the marking and spacing waves are combined with the local wave and respectively transformed by this combination into impulses of opposite directions and unequal amplitudes, a device having a high time constant whereby the succession of said impulses produces an undulating current whose sign is depending upon the phase relation of the signal waves and the local wave, means under the control of said undulating current to maintain in quadrature the local wave and the signal waves interfering in the detector, and a phase shifter restoring the convenient phase difference of said waves for the homodyne reception of the signal.

18. A synchronizing system comprising a circuit receiving a first oscillation, a local source generating a second oscillation, means whereby the received oscillation is transformed into a synchronizing sinusoidal current whose phase differs in a fixed quantity from the phase difference of the two said oscillations, a device selectively responsive to the action of said synchronizing current, and means whereby said response controls the frequency of one of said oscillations.

19. A phase difference control system compris-

ing a circuit for a first oscillation proceeding from a Hertzian wave, a circuit for a second oscillation locally generated, means whereby the first oscillation is transformed into a sinusoidal current whose phase differs in a fixed quantity from the phase difference of the two said oscillations, a device selectively responsive to the action of said sinusoidal current whose frequency is null at synchronism, and means whereby said response controls the frequency of one of said oscillations.

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