June 15, 1937. W. RUNGE 2,083,747

SIGNALING SYSTEM

Original Filed April 25, 1931

Fig. 1

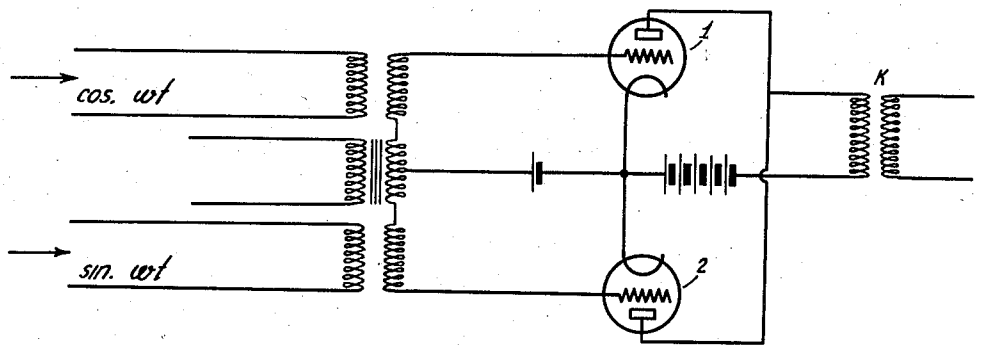
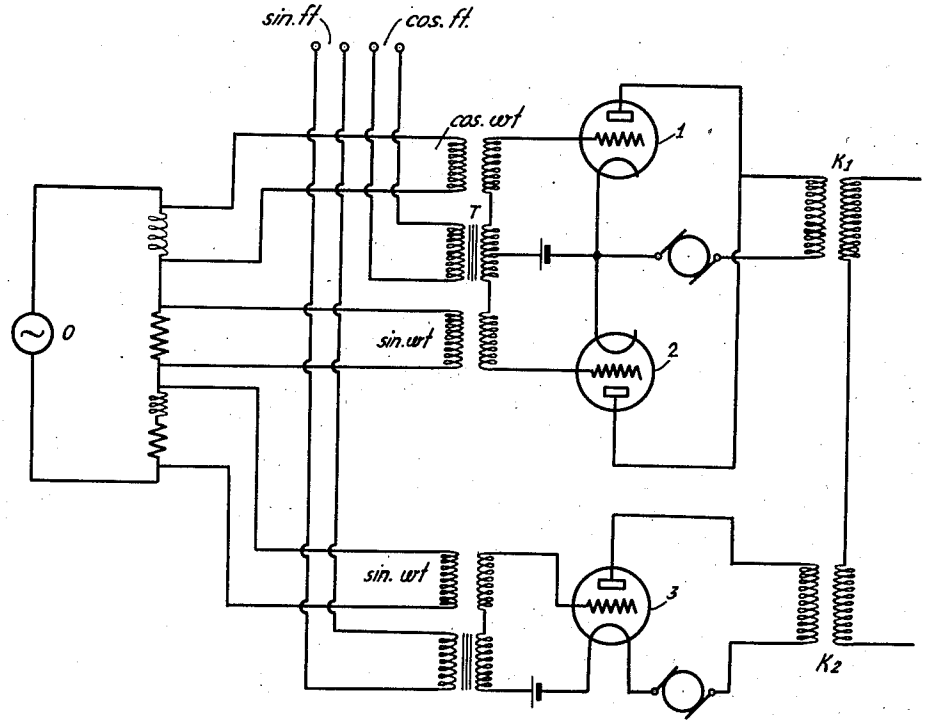


Fig. 2



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SIGNALING SYSTEM

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14 Claims. (Cl. 179—171)

A transmitter, whose energy is altered at the rate or rhythm of some audio frequency signals, sends out not only the carrier frequency at which it is excited, but, as a result of the action of the amplitude variations on the carrier frequency, also sends out additional frequencies known as the side-band frequencies, which are produced above and below the so-called carrier wave or frequency. If the transmitter is modulated with a mixture of frequencies, as in the case of voice modulation, there arises an upper and a lower side band frequency for each such modulating frequency. For this reason one speaks of the upper and the lower side band rather than of individual or distinct frequencies. To each frequency in the upper side band there corresponds a frequency in the lower side band, both of which result from the same modulating frequency and on reception of the signal both furnish the same demodulated frequency. Hence, in order to transmit signals, but one of the said two side bands is required. It is a suggestion well known in the prior art to narrow down the aggregate frequency band required or at least occupied by a modulated sender by sending out only the carrier wave and one side band, while the other side band is suppressed.

The carrier wave itself does not contain anything of the frequencies to be transmitted. Fundamentally speaking, it is thus admissible to omit the same in transmissions, and to generate it locally at the receiving end and thereupon add it. Such addition of the carrier to one side-band is especially simple if upon transmission not only the carrier, but also one side band, have been omitted. By cutting out the carrier wave, a large amount of the energy which is otherwise expended at the sending end will be saved.

In the light of what has been pointed out above, it is desirable to provide ways and means whereby in the sending of modulated oscillations, one side-band may be suppressed, so that only the carrier wave and the other side-band are transmitted, or whereby the carrier wave and one side-band are suppressed, with the result in the latter instance that only one side-band is sent out.

The circuit for, and the method of signaling in accordance with the present invention, will be better understood by the following detailed description thereof and therefrom when read in connection with the drawing, in which:

Fig. 1 shows, merely for purposes of illustration, a circuit arrangement whereby phase modulation of a carrier wave may be accomplished. Fig. 1 serves to describe and illustrate the principle of applicant's invention; while

Fig. 2 shows a phase modulator similar to the arrangement of Fig. 1, in which novel means have been added for accomplishing amplitude modulation of the carrier and combining the same with the phase modulated wave.

According to the invention this is accomplishable in the following way. If the amplitude of an oscillation is controlled at audio frequency rhythm, then, in addition to the carrier wave, there arise two side frequencies. If, on the other hand, the amplitude of an oscillation is left entirely constant, while the phase is altered at the rate or rhythm of the audio frequency to be transmitted, then, in addition to the carrier wave, there are set up also two side-band frequencies. It can be shown that if conditions are conveniently chosen the carrier frequency and one side frequency can be made the same as to amplitude and phase as those which arise by amplitude modulation, while the other side frequency has phase opposite that obtained in amplitude modulation. The sum total of oscillations modulated by two such dissimilar modulation methods therefore contains the carrier wave and one side band only inasmuch as the other side-band occurs in both modulation methods with opposite signs. The difference of both oscillations modulated in this different manner contains only one side-band, the carrier and the respective second side-band occurring in both modes of modulation with the same sign so that they drop out in the difference. This situation is demonstrated by the following calculation:

An oscillation whose amplitude has been modulated, obeys this law:

$$U_a=(1+k \sin ft) \cdot \sin \omega t \qquad (1)$$

where ω is the carrier wave to be modulated, f the modulation frequency to be transmitted, k the degree of modulation. According to well-known trigonometric rules the right-hand side may be made to assume this form:

$$U_a=\sin \omega t+\tfrac{1}{2}k \cos (\omega-f)t-\tfrac{1}{2}k \cos (\omega+f)t \qquad (2)$$

In this expression, the first sum at the right of the equality sign is the carrier oscillation, the second one the lower side frequency, and the third one the upper side frequency.

Acting upon the phase by the audio frequency, the current transmitted obeys this formula:

$$U\varphi=\sin (\omega t+\varphi \cos ft) \qquad (3)$$

This expression is expressible also in this way:

$$U\varphi=\sin \omega t \cdot \cos (\varphi \cos ft)+ \cos \omega t \cdot \sin (\varphi \cos ft) \qquad (4)$$

Making φ less than $\frac{1}{2}$, then the coefficient of $\sin \omega t$ can be put equal to unity with sufficient correctness, while in the coefficient of $\cos \omega$ the sine may be put equal to its arc. Then:

$$U\varphi=\sin \omega t+\cos \omega t \cdot \varphi \cdot \cos ft. \qquad (5)$$

Resolving the product cos.cos, then:

$$U\varphi=\sin \omega t+\tfrac{1}{2}\varphi \cos (\omega-f)t+\tfrac{1}{2}\varphi \cos (\omega+f)t \qquad (6)$$

In this latter expression sin ωt denotes again the carrier wave to be modulated; $\omega - f$ is the lower side frequency, $\omega + f$ the upper side frequency, while φ in analogy with the amplitude modulation, can be designated as the "phase modulation degree".

Comparing the final formula for U_a and for U_φ it will be seen that, if $\varphi = k$ the two expressions in the carrier frequency and the lower side-band agree as to frequency, phase and amplitude, whereas in the upper side band, while there is agreement as to frequency and amplitude, there occur different signs. The sum total of both oscillations therefore is:

$$U_s = 2 \sin \omega t + \varphi \cos (\omega - f) t$$

It includes the carrier frequency and the lower side-band frequency, the upper side frequency has been eliminated. The difference between both oscillations becomes:

$$U_a = \varphi \cos (\omega + f) t$$

The carrier and one side-band have been eliminated.

For practicing phase modulation and amplitude modulation, as outlined above, recourse may be had to different circuit schemes. Although applicant does not wish to limit himself to specific circuit arrangements, except as marked out in the claims below, several arrangements illustrative of the invention will be described.

One embodiment is shown in Figure 1. The grid electrodes of two tubes 1 and 2 are fed with carrier wave potentials cos ωt and sin ωt displaced by 90 degrees. The two tubes are modulated push-pull-fashion by the audio frequency energy by way of transformer T. The audio frequency potentials are applied to the control grids of tubes 1 and 2 differentially, that is, out of phase, as shown. Phase modulation is accomplished and phase modulated signals appear in the transformer K. This has been shown mathematically above but will perhaps be more readily understood from the following, if we visualize the vectors and resultant of the carriers and modulating frequencies combined. Assume we draw a vector of a length E_1 to represent sin ωt and from the same origin a vector E_2 displaced 90° to represent cos ωt. The resultant will lie between these two vectors. Now the modulation potentials are applied differentially to the grids of the tubes 1 and 2. When one grid rises in potential the other falls. The vectors sin ωt and cos ωt will alternately decrease and increase in length and the resultant will shift between these two vectors. This is phase modulation unaccompanied by material amplitude modulation since the length of the resultant will not change to a great extent. The plates of both tubes are connected in parallel and the currents in their circuits flow through a joint coupling transformer K with which the output or utilization circuit may be coupled.

Another embodiment of an assembly is shown by way of example in Figure 2. From the radio frequency oscillator O tubes 1 and 2 are supplied by carrier wave potentials displaced by an angle of 90 degrees. Audio frequency modulation as before takes place through transformer T. 3 denotes the tube in which the carrier oscillations are modulated in amplitude. The output circuits of tubes 1, 2 and 3 act by way of coupling transformers K_1, K_2 upon a joint circuit. In the transformer K_1 we have phase modulation produced in the same manner in which phase modulation was produced in Figure 1. In the transformer K_2 we have amplitude modulation. Here an object is to eliminate a carrier and a side band so that we have left a single side band for transmission. The manner in which this is accomplished will be clear if we consider the carrier and side bands resulting from amplitude and phase modulation. As pointed out hereinbefore (page 1, seventh paragraph, and Equations 2 and 4), if the components resulting from phase modulation and amplitude modulation are added the side bands of unlike sign cancel and we have a carrier and side band left which are the sum of the carriers and side bands resulting from the phase and amplitude modulation. If we take the difference of the energies resulting from phase and amplitude modulation under proper conditions, that is, when the two carriers are 180° out of phase, so that they cancel, we have left but one side band which is the sum of one of the side bands resulting from phase modulation and one of the side bands resulting from amplitude modulation. Conditions are such in the circuit of Figure 2 as to produce this single side band in the output circuit. It is also feasible to obtain the desired effect when one and the same carrier is consecutively modulated in phase and in amplitude. In this instance, only one side-band will be suppressed.

If the output circuits of tubes 1, 2, and 3 are properly arranged the phase modulated and amplitude modulated outputs may be added or combined to produce a carrier and one side band for signaling purposes.

Having thus described my invention and the operation thereof, what I claim is:

1. The method of producing a predetermined phase difference between several portions of energy resulting from the demodulation of a carrier modulated at signal frequency which includes the steps of, modulating in phase and in amplitude carrier energy respectively by two components of different phase of the signal energy and combining the resultant modulated energy.

2. The method as recited in claim 1 in which the resultant modulated energy is combined to obtain the difference of the components resulting from the modulation in phase and in amplitude of the carrier.

3. An arrangement for the production of modulated radio frequency oscillations in which certain components are suppressed comprising, a source of potentials of signal frequency, a source of carrier frequency waves, means connected with both of said sources for modulating the phase of the carrier frequency waves in accordance with the signal potentials, means connected with both of said sources for modulating the amplitude of the carrier frequency waves in accordance with the aforesaid signal potentials, and means for combining the energy resulting from said modulating steps.

4. Means for modulating carrier wave energy at signal frequency and for suppressing from the resultant modulated energy a side-band and energy of the carrier wave frequency comprising, a thermionic relay including a pair of thermionic tubes having their input electrodes connected in push-pull relation by an input circuit and their output electrodes connected in parallel, a circuit for impressing potentials of carrier frequency energy of unlike phase on said input circuit, a circuit for impressing modulating potentials on said input circuit and from said input circuit differentially to the input electrodes of said tube, a

third thermionic tube having input electrodes, and output electrodes, a circuit for impressing carrier frequency energy of predetermined phase on the input electrodes of said third tube, a circuit for modulating in amplitude the carrier frequency impressed on said third tube in accordance with modulating potential of predetermined phase, and output circuit connected with the output electrodes in said third tube, and a circuit coupled to the output circuits of said third tube and said first-named tubes.

5. A device for varying the phase of carrier frequency oscillations at signal frequency and for maintaining the amplitude of said oscillations substantially constant comprising, a pair of thermionic tubes each having electrodes including an anode, a cathode and a control grid, sources of carrier frequencies of unlike phase, an input circuit including an inductance connected between the control grid and cathode of one of said tubes, a coupling between one of said sources and said inductance, an input circuit including an inductance connected between the control grid and cathode of the other of said tubes, a coupling between the other of said sources and said last named inductance, a source of modulating frequency potentials, a transformer having a secondary winding, portions of which are in each of said input circuits, and a coupling between said modulation frequency source and the primary winding of said transformer, whereby modulating potentials are applied differentially to the input circuits of said tubes.

6. Signaling means comprising, a circuit for producing high frequency oscillations modulated in phase including, a pair of thermionic tubes, each having a control grid, a cathode and an anode, a circuit for coupling the anodes of said tubes in parallel, circuits for applying carrier frequency oscillations of unlike phase but of like frequency to the control grids of said tubes, a circuit for applying modulating potentials differentially to the control grids of said tubes, whereby phase modulated oscillations appear in the circuit connected with the anodes of said tubes, a third thermionic tube having an anode, a cathode and a control grid, an output circuit connected between the anode and cathode of said third tube, means for applying carrier frequency oscillations to the control grid of said third tube, means for applying modulating potentials to the control grid of said third tube, whereby oscillations modulated in amplitude at signal frequency appear in the output circuit of said third tube, and a circuit for combining the modulated oscillations appearing in the output circuit of said third named tube with the modulated oscillations appearing in the output circuit connected with said first named pair of tubes to obtain a single side band.

7. The method of producing a predetermined phase difference between several portions of energy resulting from the modulation of a carrier at signal frquency which includes the steps of, modulating in phase and in amplitude carrier energy respectively by two components of different phase of the signal energy and combining the resultant modulated energy to obtain the sum of the components resulting from the modulation in phase and in amplitude of the carrier.

8. The method of signaling by means of high frequency carrier waves and oscillations of lesser frequency which includes the steps of separately modulating the phase of the high frequency carrier waves in accordance with said oscillations of lesser frequency, separately modulating the amplitude of said high frequency carrier waves with said oscillations of lesser frequency, and combining the energy resulting from said modulation processes.

9. The method as recited in claim 8 in which the energies resulting from said modulating steps are combined additively.

10. The method of signaling, as recited in claim 8, in which the energies from said modulating steps are combined subtractively.

11. Signaling means comprising in combination a phase modulator, an amplitude modulator, a work circuit coupled to the output of both of said modulators, a source of modulating potentials, phase displacing circuits coupling said source of modulating potentials to each of said modulators, a source of carrier waves, and separate circuits one or more of which include phase displacing means coupling each of said modulators to said source of carrier waves.

12. A phase modulator comprising a pair of electron discharge devices each having an anode, a control electrode, and a cathode, means for energizing the control electrodes of said devices by phase displaced oscillations of like frequency, means directly connecting the cathodes of said tubes together, means directly connecting the anodes of said tubes together, an alternating current output circuit connecting the anodes to the cathodes of said tubes, a source of modulating potentials, an impedance, a circuit connected with said source of modulating potentials for impressing modulating potentials on said impedance and a circuit connecting points on said impedance at which said modulating potentials are of unlike phase to the control electrodes of said devices, to thereby vary in unlike manner the conductivity of said devices in accordance with modulating potential variations in said impedance.

13. In a phase modulation system, a pair of electron discharge devices each having an anode, a cathode and a control grid, means connecting the anodes of said devices directly together, means connecting the cathodes of said devices directly together, an alternating current output circuit connected between said anodes and cathodes, means for supplying oscillations of carrier wave frequency to the control grid and cathode of one of said devices, means for supplying oscillations of the same frequency but of different phase to the control grid and cathode of the other of said devices and means for applying modulating potentials in phase displaced relation to the control grids of said devices.

14. In a phase modulation system a pair of electron discharge devices each having an anode, a cathode and a control grid, means directly connecting the anodes of said devices together, means directly connecting the cathodes of said devices together, an alternating current output circuit connected between said anodes and cathodes, a circuit connected with the control grid and cathode of one of said devices for supplying oscillations of carrier wave frequency to the control grid and cathode of said device, a circuit connected with the control grid and cathode of the other of said devices for supplying oscillations of the same frequency but of different phase to the control grids of said devices, an impedance connecting the control grids of said device in push-pull relation, said impedance being connected to the cathodes of said devices, and means for applying modulating potentials to said impedance.

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