

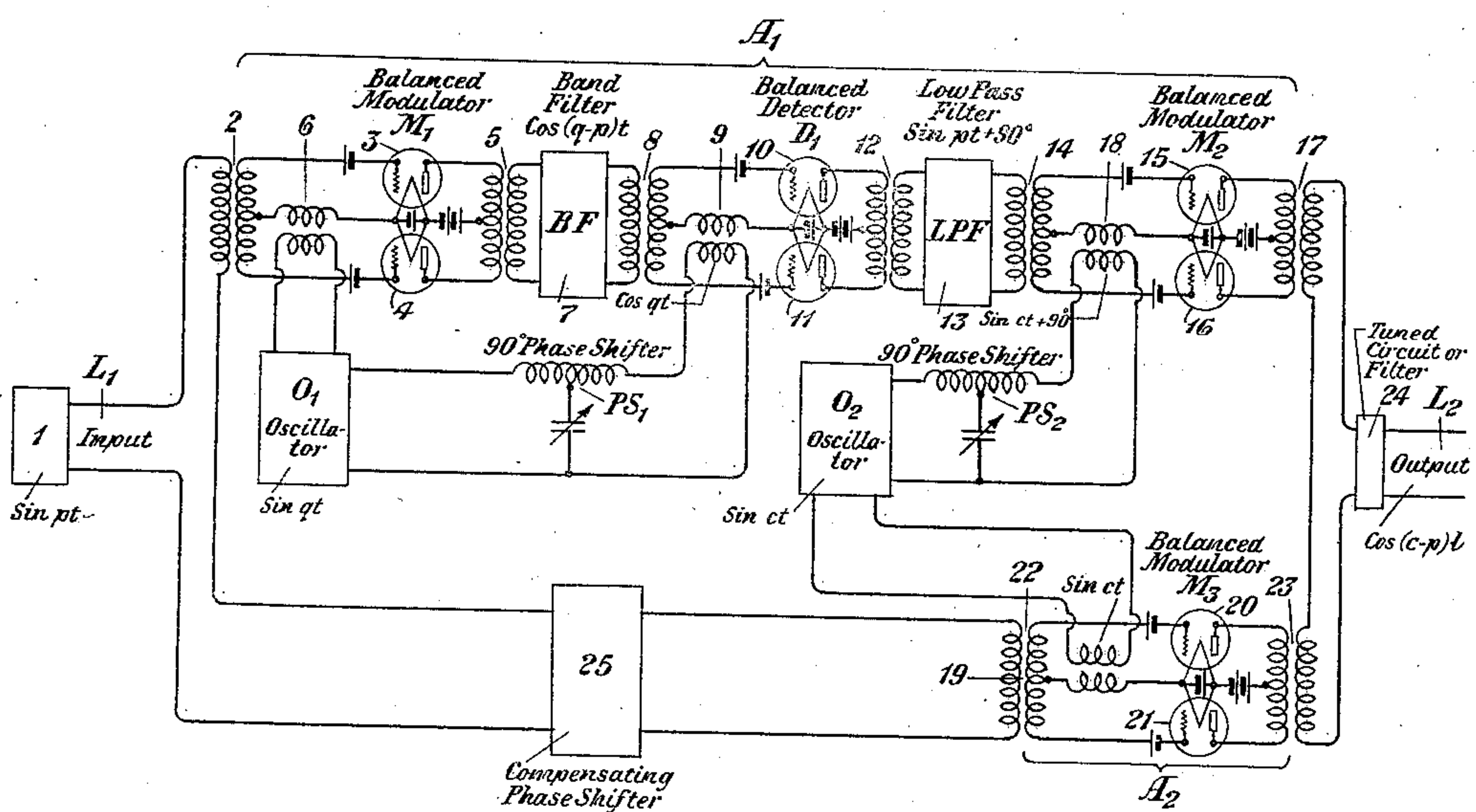
Feb. 18, 1930.

A. CARPE

1,747,160

SINGLE SIDE BAND CARRIER SYSTEM

Filed Sept. 22, 1926



INVENTOR
Allen Carpe
 BY *g r 40 c*
 ATTORNEY

UNITED STATES PATENT OFFICE

ALLEN CARPE, OF NEW YORK, N. Y., ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK

SINGLE-SIDE BAND-CARRIER SYSTEM

Application filed September 22, 1926. Serial No. 137,134.

This invention relates to high frequency signaling systems, and particularly to a method and means for the production of a single side band.

5 In high frequency signaling systems, as, for example, a carrier system in which it is desired to transmit only one side band over the system, it is customary to eliminate by means of a filter the other side band produced
10 by the modulation of the carrier by the signal to be transmitted. Except for the loss of energy represented by the suppressed side band, this method of elimination is satisfactory where the frequencies involved are of
15 the order now employed upon carrier systems. As the frequencies increase, the difficulty in eliminating the unwanted side band by means of a filter becomes more pronounced, and with frequencies of the order of 1,000
20 kilocycles it is practically impossible to eliminate the unwanted side band by filters unless the signal currents are raised to that frequency through two or more stages of modulation with filters in each stage to eliminate
25 the unwanted band. Such a system is, of course, expensive to build and maintain, and there are other reasons why this practice is undesirable.

30 This invention resides in a method and means for discriminating against undesired modulation products by phase balance. More particularly it resides in the production of one side band only, by the direct modulation of the high frequency carrier by a low frequency signal.
35

Other objects of this invention will be apparent from the following description when read in connection with the attached drawing showing schematically a form of embodiment
40 of the invention.

45 In the drawing, the line L_1 represents an input circuit having a source of signals 1 connected therewith. L_2 represents an output circuit which may be either a wire circuit or the input to a radio antenna. The

input circuit L_1 is connected with two branches A_1 and A_2 , which in turn are connected with the common output circuit L_2 . The branch A_1 includes a balanced modulator M_1 which is connected with the input circuit by means of the transformer 2. This
50 modulator includes the tubes 3 and 4 which are symmetrically connected with the secondary winding of the transformer 2 and also with the primary winding of the transformer 5. An oscillator O_1 is arranged to impress a voltage of a carrier frequency upon the winding 6 which is similarly connected with the grids of the tubes 3 and 4. The frequency produced by this oscillator should be
55 such that one of the side bands appearing in the modulator output may be suppressed by means of the band filter 7 which is connected with the secondary of the transformer 5. This filter is also connected by the transformer 8 with the detector D_1 the function of which is to detect the signal which was impressed by the line L_1 upon the modulator
60 M_1 . This detecting step is effected by oscillations from the source O_1 , which, of course, are of the same frequency as those applied to the modulator M_1 , but differ in phase by 90° from the latter as the result of the action of the phase shifter PS_1 inserted
70 between the oscillator O_1 and the winding 9 connected with the common conductor in the input circuits of the tubes 10 and 11 of the detector D_1 . The output side of this detector is connected by the transformer 12
75 with a low-pass filter 13 whose cut-off point is above the limit of the signal transmitted by the line L_1 . This filter is connected by transformer 14 with the input side of the modulator M^2 comprising the tubes 15 and 16 which are symmetrically connected with the
80 windings of the transformers 14 and 17. The winding 18 in the input circuits of the tubes 15 and 16 is connected with a source of high frequency oscillations O_2 , the connection including a phase shifter PS_2 whose func-
85

tion is to shift by 90° the phase of the current applied by the oscillator O_2 to the modulator M_2 . The output side of this modulator is connected by transformers 17 with the line L_2 . As mentioned before, the input circuit L_1 is connected by the transformer 19 with the modulator M_3 comprising tubes 20 and 21, which are symmetrically connected with windings of the transformers 22 and 23. The common conductor in the input side of this modulator is connected with the source of high frequency oscillations O_2 . This connection, it will be seen, includes no phase shifting device, so that the high frequency oscillations applied by O_2 to the input side of the modulator M_3 are 90° out of phase with oscillations of the same frequency applied by O_2 to the modulator M_2 .

In addition to the desired phase displacements produced by the action of the phase shifters PS_1 and PS_2 , and explained in detail below, the currents flowing through the two paths A_1 and A_2 will be subject to unavoidable additional phase displacement produced by the transformers and filters contained in these circuits. In order to compensate for these additional phase displacements, a compensating phase shifter 25 is shown in the path associated with the modulator M_3 , and it is to be understood that this compensating phase shifter is so designed that its net phase displacement will be equal to that produced by those elements of the path A_1 which are not otherwise duplicated in the path A_2 , i. e., by that portion of path A_1 between transformer 2 and low-pass filter 13, inclusive.

The manner in which the foregoing system functions in order to produce a single side band of modulated high frequency oscillations by direct modulation of the high frequency carrier by the low frequency modulating current is as follows: The modulating frequency impressed by the source 1 upon the line L_1 , which frequency may represent speech, music or other sounds, has an instantaneous value which, for purposes of discussion, may be represented by $\sin pt$. This will be impressed by transformer 2 upon the branch A_1 , and by the transformer 19 upon the branch A_2 . The current impressed on the branch A_1 will be modulated by oscillations from the source O_1 having the value $\sin qt$. Since the balanced modulator M_1 suppresses the carrier frequency, there will be impressed by the transformer 5 upon the band filter 7 only the side bands of modulation and double frequency and unmodulated components. The side bands are represented by

$$\cos (q-p)t - \cos (q+p)t.$$

The band filter 7 is designed to eliminate one of the side bands, as, for example, the upper one represented by $\cos (q+p)t$ and also the double frequency and unmodulated compo-

nents, so that there will be impressed by the transformer 8 upon the input side of the detector D_1 only the lower side band represented by $\cos (q-p)t$. There will also be impressed upon the same input circuit, but in a different manner, oscillations of the frequency q from the source O_1 , but differing in phase by 90° from the oscillations of the same frequency that were impressed upon the input side of the modulator M_1 . There will, of course, appear in the output side of the detector D_1 the sum and the difference frequencies resulting from the detecting operation, which may be represented by

$$\cos (q-p)t \sin (qt+90^\circ)$$

which equals

$$1/2 [\sin (pt+90^\circ) + \sin [(2q-p)t+90^\circ]]$$

From the expression appearing in the preceding line, it will be seen that the output of the detector includes not only several unwanted components, but also the original modulating current $\sin pt$, which, however, differs in phase by 90° from the modulating current that is flowing over the circuit L_1 . The unwanted components, namely, those represented by the expression

$$\sin [(2q-p)t+90^\circ]$$

are eliminated by means of the low-pass filter 13, and the modulating frequency $\sin (pt+90^\circ)$ is then impressed by the transformer 14 upon the input side of the modulator M_2 . It should be clearly understood that at the same time there is being impressed upon the modulator M_3 by the transformer 19 the original modulating current represented by $\sin pt$. That is to say, the modulating currents being presented to the modulators M_2 and M_3 differ in phase by 90° . Similarly, the carriers of frequency $C/2\pi$ which are to be modulated differ in phase by 90° . The output of the modulator M_2 includes two side bands which may be represented by

$$\cos (ct+90^\circ-pt-90^\circ) - \cos (ct+90^\circ+pt+90^\circ)$$

which, when simplified, equals

$$\cos (ct-pt) - \cos (ct+pt+180^\circ).$$

The side bands in the output of the modulator M_3 are represented by

$$\cos (ct-pt) - \cos (ct+pt).$$

The output currents of both modulators will be impressed by the transformers 17 and 23 upon the output circuit L_2 and will combine therein. The lower side bands represented by $\cos (ct-pt)$ will add. The upper side band, namely, $\cos (ct+pt)$ produced by M_2 differs in phase from the same side band produced by M_3 by 180° , so that these side bands cancel. This leaves in the circuit L_2 only the single side band which is represented by $\cos (c-p)t$, and unmodulated and double frequency components which may be eliminated

by a simple tuned circuit or filter such as 24.

It will be seen from the foregoing description that the steps performed by that portion of the circuit A_1 between the transformers 2 and 14 consist in the shifting in phase of the modulating current impressed by the line L_1 upon the branch A_1 . The two parts of the same modulating current which differ in phase by 90° are then impressed upon modulators in which the same carrier frequency is employed, but differing in phase by 90° . This results in the production of a single side band representing the modulation of a high frequency carrier by means of a lower frequency modulating current, such as speech or music. Since this high frequency carrier may be of the order of 1,000 kilocycles, it will be appreciated that its direct modulation by a low frequency modulating current representing the range of speech or music represents a substantial improvement upon systems of the prior art. To accomplish the modulation of such a high frequency in the older systems it would have been necessary to modulate a carrier of say 30,000 cycles by the speech current, and after selecting one of the side bands to modulate, by means of this side band, a second carrier of the order of 150 or 200 kilocycles. One of the side bands of this modulation would then have been selected and used to modulate the higher frequency of say 1,000 kilocycles. It will be seen, therefore, that my invention constitutes a simple method and means for the direct modulation of a high frequency by a low frequency modulating current to produce a single side band for transmission.

It will furthermore be seen that by means of the arrangement shown not only will the modulating currents be shifted in phase, but the shifting applies uniformly to all frequencies present in the two currents. Thus, in the system disclosed hereinbefore, not only have the current waves been shifted, but the shifting has been accomplished without changing the values of the component frequencies in the shifted wave. Therefore, each component frequency has the same value after the shifting has occurred as it possessed in the original wave so that in the final modulating process, there will be complete cancellation of the undesired side-band produced by the modulating currents and carrier currents that are out of phase.

It will also be understood that while phase displacements of 90° have been described above in the case both of the modulating and the carrier frequency, the desired result will be obtained by using any phase differences which will cause one side-band to be combined in the common output circuit with a net phase difference of 180° or any odd multiple thereof, while the other side-band is combined at some other phase angle such that it is not cancelled or suppressed.

It will further be evident that the same general method, described herein as applied to the elimination of one side-band, may be applied for the purpose of discriminating against any unwanted product of modulation which may be balanced out by phase opposition in the output circuit.

While this invention has been disclosed in a particular form, it is to be understood that it is capable of embodiment in other forms without departing from the spirit and scope of the appended claims and any form of modulating devices, such as magnetic modulators, may be used.

What is claimed is:

1. The method of producing a predetermined phase difference between two portions of a modulating current, which consists in modulating with one portion of said current a carrier current of different frequency to produce side bands of the carrier, selecting one side band, modulating with the selected side band a second carrier current of the same frequency as that used in the first modulating operation but differing in phase therefrom by the same predetermined angular difference desired to be produced between the said portion of the modulating current, and selecting from the products of modulation the current having the same magnitude and frequency as the original modulating current but differing in phase therefrom by the predetermined phase angle.
2. The method of producing a predetermined phase difference between two portions of current the value of which is $\sin pt$, which consists in modulating a carrier of value $\sin qt$ with one portion of the current $\sin pt$, selecting one of the side bands such as $\cos (q-p)t$, producing a current of the same frequency as the original modulating current $\sin pt$, but differing from the original current by the phase angle ϕ , by beating the selected side band with a carrier $\sin qt + \phi$.
3. The method of producing a predetermined phase difference between two portions of current the value of which is $\sin pt$, which consists in modulating a carrier $\sin qt$ with one portion of the current $\sin pt$, selecting one of the side bands such as $\cos (q-p)t$, producing a current of the original modulating frequency p but differing therefrom by 90° , by beating the selected side band with a carrier $\sin (qt + 90^\circ)$, and selecting the component $\sin (pt + 90^\circ)$.
4. In a single side band carrier system the combination with a source of signaling current of a source of carrier current, means to modulate the carrier current by the signaling current, means to select one of the side bands resulting from modulation, a second modulating device, means to apply to the said modulating device a carrier current from the said first mentioned source, the connection including means to shift the phase of the carrier

current a predetermined angular distance,
and means to select the signaling frequency
current from the products of modulation, the
said current differing in phase from that pro-
duced by the original source by the predeter-
mined phase angle by which the carrier is
shifted.

In testimony whereof, I have signed my
name to this specification this 20th day of
September, 1926.

ALLEN CARPE.