Jan. 26, 1926. 1,571,006

R. V. L. HARTLEY

SIGNALING SYSTEM

Original Filed Sept. 8, 1920

Fig. 1.

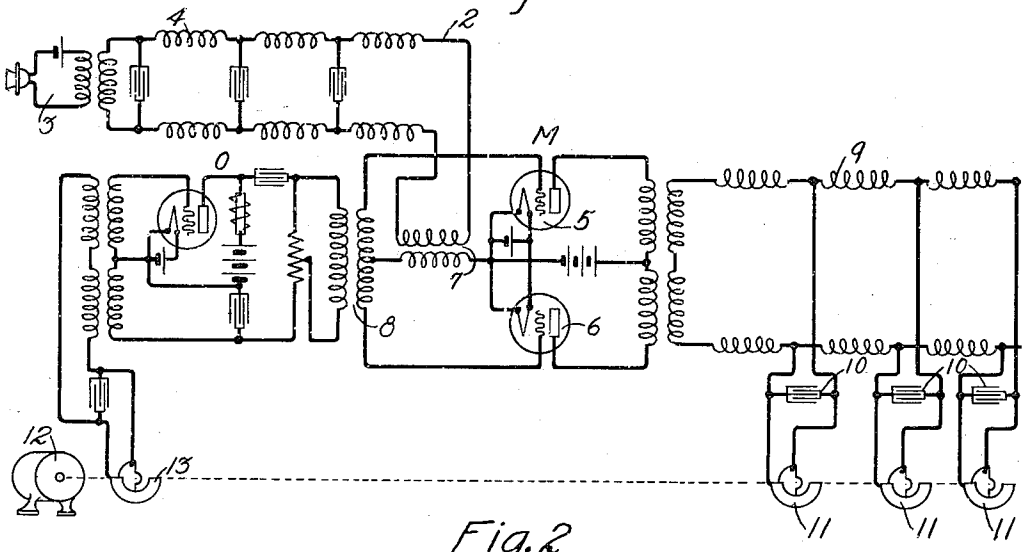


Fig. 2

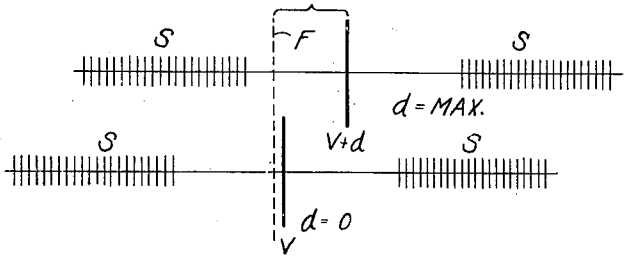
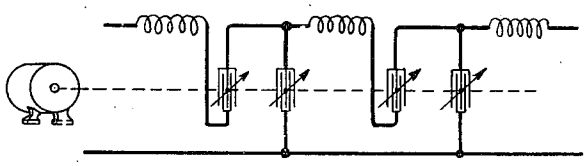


Fig. 3.



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by W. E. Beatty. Atty

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UNITED STATES PATENT OFFICE.

RALPH V. L. HARTLEY, OF EAST ORANGE, NEW JERSEY, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

SIGNALING SYSTEM.

Original application filed September 8, 1920, Serial No. 408,890. Divided and this application filed July 6, 1921. Serial No. 482,710.

To all whom it may concern:

Be it known that I, RALPH V. L. HARTLEY, a citizen of the United States of America, residing at East Orange, in the county of Essex, State of New Jersey, have invented certain new and useful Improvements in Signaling Systems, of which the following is a full, clear, concise, and exact description.

The present invention relates to the transmission of electrical currents or waves for signaling or other purposes. More particularly it relates to an arrangement for varying the transmission characteristic of a multi-section network, more specifically an arrangement for continuously varying a characteristic of an electrical network, such as the discriminating characteristics of an electric wave filter, for example.

This invention will be hereinafter described in connection with a secret signaling system in which is employed a sustained wave modulated or controlled in accordance with the wave to be secretly transmitted. A sustained wave used in this manner is sometimes called a carrier wave, and generally has a constant high frequency. In the present invention, however, the carrier wave may be audible and is made to have a cyclically varying frequency, the rate of variation being very low in comparison with the frequency of the signaling waves to be transmitted.

It is well known that when a carrier wave is modulated by a range of low frequency waves such as speech waves, a number of different frequency components result, among which are an unmodulated one of the original carrier frequency and two sidebands representing the sum and difference, respectively, of the carrier frequency and the speech frequencies, if all of these components are transmitted over a telephone line, the speech frequency can be received by the use of a simple detector. If the unmodulated carrier frequency component is completely suppressed and only one sideband is transmitted, it is impossible to receive the speech by simple detection, but if a wave of the carrier frequency is combined at the receiver with the transmitted sideband, a detector will yield the speech waves. A system in which only one sideband is transmitted, therefore, possesses a considerable degree of secrecy, since an outsider would have some difficulty in discovering the frequency of the wave which it is necessary to use at the detector in order to receive speech. It is conceivable, however, that one might hit upon the proper frequency by trial, and when once this has been discovered there would be but little difficulty in receiving the speech.

In accordance with this invention it is proposed to use a continuously varying carrier frequency in order to make it necessary to know not only the carrier frequency at any instant, but the manner in which it is varied before the transmitted message can be intelligently received. By varying the carrier frequency over a considerable range, and especially by employing a more or less complex scheme of variation of the carrier frequency, a high degree of secrecy is obtainable.

If a wire transmission system is used, it is desirable to suppress completely the currents of the original voice frequencies, since if any of these get to the line it might be possible to filter them out and amplify them sufficiently to render them receivable. It is also necessary to suppress practically completely the unmodulated carrier frequency component and one of the sidebands. It is desirable also to suppress double frequency components and the other frequency components which are not to serve any useful purpose. If the lower sideband is the one which is to be transmitted, and if the lowest essential frequency represented in it is above the highest voice frequency then a high pass and a low pass filter in series in the output of the modulator can be used. The high pass filter will suppress all currents of the frequencies from zero up to the upper limit of the voice range, while the low pass filter will suppress all currents of frequencies higher than the lower sideband including components of the carrier frequency and the harmonics. If the lower sideband, however, contains frequencies so low as to overlap the voice range, a filter cannot be used to suppress the voice, but a balanced modulator may be used for this purpose as will be described hereinafter.

In either case a low pass filter may be used to suppress the unmodulated carrier component the upper sideband and the high harmonics. It will be shown hereinafter, however, that if a low pass filter having a fixed cutoff frequency is used to suppress the carrier it will permit of only a very limited range of variation of the carrier frequency.

It is an object of the present invention to overcome this limitation and to make possible a variation of the carrier frequency over any desired range while still preventing the unmodulated component of carrier frequency and other undesired frequency components from being transmitted. In the present instance, this object is accomplished by varying simultaneously with the carrier frequency the frequency above which all frequencies are suppressed. In accordance with this invention this is done by the use of a filter having a variable cutoff.

From the detailed description of this invention given later it will be apparent to those skilled in the art that the wave filter provided in accordance with this invention with a continuously variable cutoff may be readily adapted to many important uses in transmission systems widely different from the secret carrier system specifically described.

This invention will be better understood by reference to the following detailed description taken in connection with the accompanying drawings in which Fig. 1 represents a high frequency signaling system embodying this invention; Fig. 2 is a graphic illustration of certain frequency relations made use of in describing the invention; and Fig. 3 is a modification of certain details of Fig. 1.

In the system to be described, it is assumed that the carrier frequency $v+d$ varies cyclically in any desired manner between limits which are determined by d varying between zero and a predetermined limiting value. If the speech frequency band as a whole is represented by s and if the carrier wave is modulated by currents of speech frequencies, as will be assumed in the present case, the resulting components will be of frequencies $v+d-s$, $v+d$, and $v+d+s$. If the lower band of frequency $v+d-s$ alone is to be transmitted, an upper limiting or low pass filter will be used to enable the band $v+d-s$ to be transmitted but to suppress the higher frequency components including both the unmodulated carrier components and the upper sideband. This means that the cutoff frequency of the filter must always lie between the carrier frequency $v+d$ and the frequency in the band $v+d-s$ lying nearest to the carrier frequency. The permissible range of variation of the carrier frequency is limited, therefore, to something less than the lowest essential voice frequency. This is illustrated in Fig. 2. The upper portion of the diagram represents the position of the speech modulated wave in terms of frequency relative to the cutoff frequency of the filter at the instant when the carrier frequency has been varied to its upper permissible limit (d=max.) and the lower portion of the figure represents the conditions at the instant when the carrier frequency has its lowest frequency value ($d=o$). The carrier frequency is in this figure denoted by the heavy vertical line. The sidebands are denoted by s, the one to the left of the carrier frequency being assumed to be the lower and the one at the right the upper sideband. If the filter is so designed that all frequencies to the left of the cutoff frequency F of the filter are transmitted while all frequencies to the right are suppressed, it is seen that in both extreme conditions i. e. $d=o$ and d=max., the lower sideband is transmitted but the carrier and the upper sideband are suppressed. If the carrier should be varied to a higher limit than that shown by d=max., it will be seen bearing in mind that the sidebands would be shifted with the carrier, that some of the lower sideband would be thrown into the suppression range of the filter and this would result in impairing the transmission of the speech. If the carrier goes to a lower value than that indicated by $d=o$, it will pass into the transmission range of the filter. It is evident therefore that with a filter having a fixed cutoff, the maximum permissible range of variation of the carrier frequency is somewhat less than the frequency interval between the carrier and the nearer edge of the sideband.

According to the present invention, the cutoff frequency F is changed with the carrier so that to whatever extent the carrier frequency shifts, the cutoff frequency changes in such a manner as to suppress the carrier, but to permit the transmission of one of the sidebands. One arrangement for accomplishing this is shown in Fig. 1.

In this figure a transmitting arrangement is shown. The modulator M is supplied with carrier oscillations from the generator O and with speech frequencies from the circuit 2. The speech waves originate in the microphone circuit 3, which is coupled to the circuit 2 through a low-pass filter 4. This filter is so designed as to transmit all of the essential voice frequencies, but to suppress the high harmonics of the voice so that essential speech frequencies confined to a limited range are used to modulate the carrier. The modulator M is of the balanced type comprising the two discharge devices 5 and 6 connected so as to suppress transmission of the speech waves. The speech waves, it will be noted, are impressed upon the

common connection between the filaments and the grids through the coil 7, while the carrier wave from the oscillator O is impressed in an opposite sense upon the two tubes by means of the coupling 8. Due to the mode of connection employed here, the unmodified voice frequency components are suppressed, but the unmodified carrier component will be transmitted. The carrier frequency may be high in comparison with speech frequencies but it may also be of audible frequency. There will be no confusion of the original speech currents and the sideband currents for the reason that the former are not transmitted by modulator M.

A filter 9 is employed to suppress the carrier frequency, but to permit the transmission of the lower sideband resulting from modulation of the carrier by the speech frequency currents. The filter 9 is, as is also the filter 4, of the general type described in the patent to Campbell, No. 1,227,113, dated May 22, 1917, but filter 9 is provided with means for making its upper limiting frequency variable at will. The filter 9 comprises a number of sections each of which includes inductive elements in series with the line and capacitative elements in shunt of the line. The cutoff frequency of the filter depends upon the product of the inductance and the capacity values, and hence by varying the magnitude of either the inductance or the capacity, it is possible to vary the cutoff frequency. In the drawing, the capacity in shunt of the line consists of fixed capacity elements 10 and variable capacity elements 11 in parallel with each other. The variable capacity elements each comprise a stationary plate and a rotatable plate which is arranged to be driven by the motor 12, and their plates or armatures may be so designed as to introduce any desired changes into the capacity of these condensers. In this way the cutoff value of the filter may be varied in any one of a number of ways by changing the shape and size of the condensers even though the speed of rotation of the motor remains the same. As pointed out above, the carrier frequency in this system changes cyclically between predetermined limits. For introducing these frequency variations the oscillator O may be supplied with a cyclically varying capacity element 13 mounted on the same shaft as the condenser 11, and the system may be so controlled that as the carrier frequency, supplied from the oscillator O, increases or decreases, the cutoff value of the filter will follow the changes in the carrier frequency by virtue of the variations in capacity of the condensers 11. With an arrangement of this kind it is possible to vary the carrier frequency in accordance with any desired scheme of variation between relatively wide limits, and still permit the transmission of the lower sideband, but suppress the transmission of the unmodulated component of the carrier frequency.

Since in order to receive the wave transmitted from the circuit in Fig. 1, it is necessary to supply to the detector a wave of the carrier frequency, it is necessary to provide at the receiver an oscillator, the frequency of which varies in the same manner as that of the oscillator O. This may be done conveniently by providing at the receiver a constant speed motor similar to 12 and by synchronizing the movements of the two motors in any well known manner.

Fig. 3 illustrates a variable band filter having variable series and shunt capacities which may be used to replace the type of filter shown in Fig. 1. The characteristic of the filter of Fig. 3 is such that the width of its transmission band may remain approximately constant as its upper and lower cutoff frequencies simultaneously increase or decrease. This type of filter is accordingly well adapted to transmit a modulated side band of fixed range, but of varying carrier frequency.

The circuit arrangements that have been illustrated and described in connection with the variable wave filter of this invention are intended merely as representatives of preferred embodiments of the invention, and it is obvious that many other arrangements are possible and will occur to those skilled in the art, for instance the inductance instead of the capacity of the filter may be varied. The invention, therefore, is not to be construed as limited to the specific circuit arrangements that have been disclosed, but only by the scope of the appended claims.

This application is a divisional application of one filed by me on September 8, 1920, Serial No. 408,890, subject, Secret signaling.

What is claimed is:

1. In combination, an electric wave filter of a plurality of sections, each of said sections comprising a shunt impedance element and a series impedance element, said impedance elements having such values as to freely transmit frequencies of a certain range while completely suppressing other frequencies, and unitary means for simultaneously and continuously varying the value of an impedance in each of said sections to continuously vary a limit of the effective transmission band of said filter.

2. In combination, an electric wave filter of a plurality of recurring sections for freely passing a definite range of frequencies while suppressing frequencies outside of said range, a source of currents, means for varying a characteristic of the currents from said source, and means for varying the transmission characteristic of said filter simultaneously with a variation in a characteristic of the currents from said source.

3. In combination, an artificial network of a plurality of sections, a source of currents connected thereto, means for varying the frequency of the currents from said source, and means for varying an impedance characteristic of said network simultaneously with a variation in the frequency of the currents from said source.

4. In combination, an electric wave filter of a plurality of sections, a source of alternating currents connected to said filter, means for varying the frequency of the currents from said source, and means for varying the cutoff frequency of said filter simultaneously with a variation in the frequency of the currents from said source.

5. In combination, a source of currents, an outgoing line, a wave filter between said source and said line for freely transmitting a definite range of frequencies while suppressing frequencies in another range, and means for simultaneously varying the frequency of said currents and a limit of the transmission range of said filter to always keep said currents in the same range of the filter.

6. In combination, a line, a wave filter in said line comprising a plurality of sections for freely passing a definite frequency band while suppressing frequencies outside of said band, each of said sections comprising a reactance in series with said line and a reactance in shunt to said line, and unitary means for simultaneously varying both of said reactances in each of said sections to vary a limit of the band of frequencies freely passed by said filter.

7. In combination, a line, a wave filter in said line comprising a plurality of sections and having a sharp cut-off frequency, each of said sections comprising a reactance in series with said line and a reactance in shunt to said line, and unitary means for simultaneously varying said reactances while maintaining a sharp cut-off frequency.

8. In an electric system, an electric band filter of a plurality of sections, and means for simultaneously varying an impedance characteristic of each of said sections to vary the transmission band of said filter while maintaining said band at substantially the same width as regards frequency.

9. In a transmission system, a transmission circuit, a filter in said circuit preventing the transmission of currents of frequencies higher than a cutoff frequency, which is a function of the electrical characteristics of said filter, means for supplying currents of varying frequency to said circuit, and means for varying the cutoff frequency of said filter in accordance with and simultaneously with the variations of frequency of said supplied currents.

10. In combination a vacuum tube oscillator, an outgoing line, a wave filter for connecting said oscillator with said line, a reactance in said filter for determining the cutoff frequency of said filter, a reactance associated with said tube for determining the frequency of the oscillations generated, and means for simultaneously varying said reactances to maintain at all times the same relation between the frequency of the oscillations generated and the cut-off frequency of the filter.

11. In combination, a source of currents of cyclically varying frequency, a network having a desired impedance for currents generated by said source, said network comprising a plurality of sections each comprising an impedance element and unitary means for cyclically and simultaneously varying each of said impedance elements coincidently with and in accordance with said variation in the currents from said source.

12. In combination, a source of currents of varying frequency, an outgoing line, a wave filter between said source and said line for freely transmitting a definite band of frequencies and suppressing frequencies in another band, said filter comprising a plurality of sections, a reactance in each of said sections and unitary means for simultaneously varying each of said reactances simultaneously with the variations in the currents from said source to always keep said currents in the same band of the filter.

13. In combination, a source of currents, means for determining the frequency of currents from said source, a line, a wave filter of a plurality of sections between said source and said line for preventing currents from said source from being impressed on said line, an impedance element in each section of said filter and means for continuously and simultaneously varying the frequency of said generator and each of said impedances.

14. In combination, an oscillator, an impedance for determining a frequency of the oscillations generated, a line, a wave filter of a plurality of sections between said oscillator and said line for suppressing said oscillations, a reactance in each of said sections and unitary means for continuously and simultaneously varying said impedance and each of said reactances.

In witness whereof, I hereunto subscribe my name this 1st day of July, A. D. 1921.

RALPH V. L. HARTLEY.