Nov. 12, 1929. A. CARPE 1,735,037

METHOD OF AND APPARATUS FOR REDUCING WIDTH OF TRANSMISSION BANDS

Filed Aug. 12, 1926

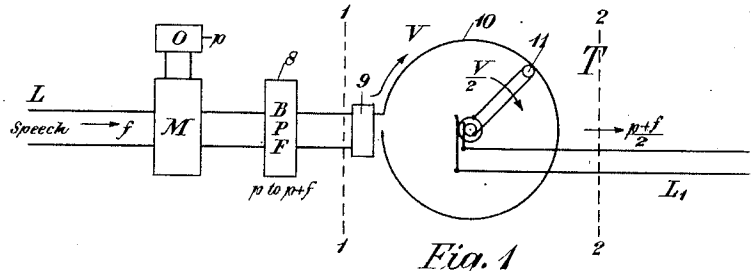


Fig. 1

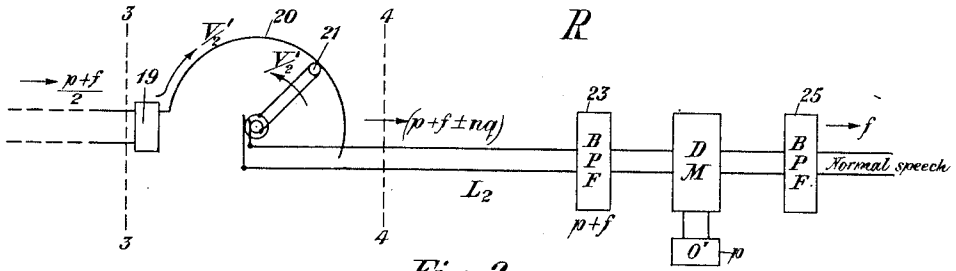


Fig. 2

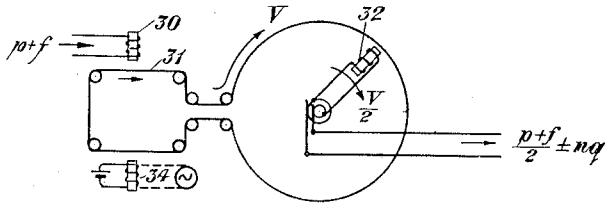


Fig. 3

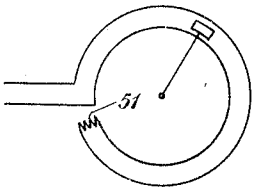


Fig. 5

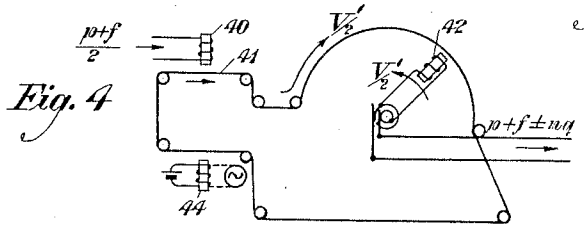


Fig. 4

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UNITED STATES PATENT OFFICE

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METHOD OF AND APPARATUS FOR REDUCING WIDTH OF TRANSMISSION BANDS

Application filed August 12, 1926. Serial No. 128,789.

This invention relates to the transmission of signals, and more particularly to methods and apparatus for reducing the width of the frequency band required for the transmission of signaling currents, such, for example, as speech currents, and is related to the invention of French and Zinn, Serial No. 755,075, filed December 10, 1924, which became Patent No. 1,671,151, May 29, 1928.

In accordance with the present invention, it is proposed to convert each frequency of a signaling band to a lower frequency in such a manner that the converted frequencies will all bear the same ratio to the original frequencies and thus change the width of the frequency band. Having so converted the signaling current, it is proposed to transmit it over a communication channel, and upon receipt, to reconvert the message to its original form.

It should be noted that the frequency conversion of the present invention is quite distinct from the type of frequency translation involved in modulation and demodulation. Modulation and demodulation consist in simply shifting all frequencies of a band up or down in the frequency spectrum without reducing the width of the band. Frequency conversion, in accordance with the principles of the present invention, however, reduces or increases all frequencies by a certain factor, and therefore reduces or increases the width of the band by this same factor.

A system involving frequency conversion for reducing the width of the frequency band required for a message has certain advantages, such, for example, as are set forth in the application of French and Zinn, noted above.

Briefly, the system described by French and Zinn consists in interrupting a signal train of waves, omitting certain elements, increasing the duration of the remaining elements and thus decreasing each frequency of the signal and decreasing the width of the frequency band. The resulting wave is then transmitted over any suitable transmission channel, and on its receipt the elements are translated or re-converted into their original shorter duration and their original higher frequencies. The gaps which then appear between the successive elements may be left blank or may be filled up by repeating adjacent elements.

In a system of the kind described, certain difficulties arise in connection with the interruption of the signal and its re-translation, and it is the purpose of this invention to reduce or eliminate such difficulties. These latter arise in part from the fact that when a train of waves is interrupted it is equivalent to modulating the train with the interruption frequency and its overtones. The method which this invention discloses for reducing the distortion due to the setting up of the modulation frequencies will be better understood as a result of the following general considerations.

Imagine a transmission channel over which a signal is passing, and associated with which there is some pick-up device, which latter may be interrupted in its function periodically. The reproduced message issuing from the pick-up device will then be the original message interrupted or chopped at regular intervals corresponding to the converted frequency. If the interruption frequency is represented by a square-topped wave, alternating between zero and unity, its formula, assuming the intervals of transmission and interruption to be of equal length is

$$i=\frac{1}{2}+a\sin qt+\frac{a}{3}\sin 3\,qt+\frac{a}{5}\sin 5\,qt+\ldots$$

For simplicity, we may assume the message frequency to be a pure sine wave given by the equation $V=\sin ft$. Then the reproduced wave is given by the product of these two, as

$$i'=\frac{1}{2}\sin ft+a\sin ft\sin qt+\frac{a}{3}\sin ft\sin 3\,qt+\ldots$$

By the usual trigonometric transformations, it may be shown that the latter is a wave containing the frequencies

$$f, f\pm q, f\pm 3\,q, f\pm 5\,q \text{ etc.}$$

which shows that in addition to the original message frequency there are present the side bands resulting from the modulation of the original message frequency with the inter-

ruption frequency and its harmonics. These are frequencies which represent the distortion introduced by chopping or interrupting the message.

One condition to consider is that in which the frequency q is greater than $2f$. In this case, it is apparent that all the modulation frequencies will fall outside the message band and may be eliminated by suitable wave filters. If, however, we consider the current on the line in this case, it will be seen that although the individual message fragments are slowed up in transmission, there is no effective decrease in the base frequency of the signal, since the individual fragments are of less duration than the signal cycle. In effect, the original message frequency is preserved, with various discontinuities and harmonics added, whose function is to transmit the interruption frequencies, which in themselves are not necessary or desirable.

Another condition to consider is that in which the frequency of interruption q is less than $2f$. In this case, an actual frequency reduction may be obtained, but it is evident that the reproduced message will contain modulation products corresponding to the original frequencies plus and minus the interruption frequencies and its harmonics which will fall in whole or in part within the message band, and which can not, therefore, be eliminated by filters. It is to be noted that the distortion is not due to the interruption frequency itself, which could be eliminated by filters if sufficiently low, but is due to side frequencies on the message frequencies which can not be so eliminated. The distortion could be minimized by making the interruption frequency low compared to the frequency f, which, in the case of speech, would certainly mean no faster than a few cycles per second, but in such a case, this would cause important parts of the message to be lost.

A further inherent difficulty of any such system resides in the fact that the transmitted currents consist of discontinuous fragments of the original message succeeding each other without intermission, and the transmission therefore requires the reproduction of discontinuities involving transient frequencies on the line. These transient frequencies will be suppressed to some extent in practice, but in order that this may be done without distorting the message, the interruption frequency must obviously be as low as possible.

In this invention, I propose to still keep the interruption frequency low compared with the transmitted signal frequency, so that in each interrupted element there will be a plurality of the signaling waves, and so that the transient discontinuities will be infrequent compared with the transmitted frequency, but, at the same time, I propose to keep the interruption frequency sufficiently removed from the signaling frequencies so that the modulation side frequencies will not fall within the signaling band. This I accomplish in the case of a normal telephone current by using this latter to modulate a carrier frequency which is high compared to the message frequencies and then interrupting this modulated wave at an intermediate frequency which is low compared to the carrier frequency, but itself is more than twice the highest frequency contained in the original message. As a result, the modulation frequencies existing in the reproduced message will be of such frequencies that they may be eliminated by suitable filters.

The invention will be better understood by reference to the accompanying drawing, in which Figure 1 illustrates a circuit suitable for the transmitting end of such a system as I propose; and Fig. 2 represents the receiving end of such a system. Figs. 3 to 5 illustrate forms of devices which may be used for conversion at the transmitting and receiving ends.

Referring more specifically to Fig. 1, a line L is shown, over which a speech wave may enter. This speech wave will be a complex one made up of a large number of frequencies varying from about 100 cycles to 5,000 cycles. For simplicity in description, this comparatively broad band of frequencies will be represented throughout by the letter f, and whenever used it is to be understood that the letter f does not stand for any single frequency, but for any and all of the frequencies in the speech range and included in the incoming message. This speech signal is impressed upon a modulator M, along with a carrier frequency p generated by an oscillator O. The modulation products are impressed upon a band pass filter so adjusted as to pass one side band only, such as that one extending from the frequencies p to $p+f$. The wave is now allowed to pass a transforming device 9 which adapts it to be propagated over a channel or path 10 of a type such that the wave velocity is the same for all frequencies, and preferably of such a type that the velocity is relatively low. A convenient form which this path 10 may take would be that illustrated in Figs. 12^a and 13^a of the application to French and Zinn. Another convenient form which it may take is illustrated in Figs. 3 and 5, to be described below. Preferably, this path 10 would be circular in form, and rotating about the axis of the circle there would be a pick-up device 11 suitably connected by contacts to the line L_1. The wave may be considered as progressing along the path 10 with a definite velocity V, and it is evident that if the pick-up device 11 is stationary, the wave will be transmitted without change from the line L to the line L_1. If, however, the pick-up 11 is rotating in the direction indicated by the arrow, then the signal message will not be transmitted to the

line L_1 so fast as it comes on to the path 10, and there will thus be an increase in the duration of any element of signal carried through, and a corresponding decrease in the frequencies and in the width of the frequency band. The change which will occur obviously will depend upon the relative velocity of the pick-up device and of the wave of the path 10. For simplicity in the description, and as an illustration, it will be convenient to take the case where the velocity of the pick-up 11 is one-half that of the propagation velocity of the wave, and this condition will be assumed throughout the remainder of the description, although it is to be specifically understood that this invention is not restricted to such velocity relations. A consideration of the wave picked up at 11 in this assumed case will make it apparent that in one complete revolution of the element 11 there will be transmitted to the line L_1 an element of the message wave which would occupy half the circumference of the path 10, and that this segment will now be spread over a length corresponding to one complete circumference of the path 10. The duration of this element, therefore, has been doubled, and each frequency in it will have been halved.

It is to be observed that when the element 11 has made one complete revolution, it skips to the beginning of the path 10, and the portion of the message which then occupies the path 10 will be omitted so far as transmission to L_1 is concerned. As a result, there will appear upon this line L_1 alternate elements of the original message, the frequency $p+f$ within each element having been reduced to $\frac{p+f}{2}$, and the elements following each other without intermission, as explained above.

The converted signal as thus produced may now be transmitted to the remote receiving station R of Fig. 2, in which virtually the reverse process is followed in order to reproduce the signal in normal form. To this end, the incoming signal of the frequency $\frac{p+f}{2}$ is allowed to enter a transforming device 19, similar to 9 and which adapts the wave to be propagated with a velocity V′ which may be the same as a velocity V of Fig. 1, over a path 20 similar to the path 10 but preferably comprising a semi-circle only. Associated with said path is a pick-up device 21 adapted to rotate about the center of the path 20 and connected by suitable contacts with the line L_2. In this case, the device 21 rotates in the opposite direction to that in which the wave is propagated over the path 20, and with a velocity V′ numerically equal to that of the velocity of propagation. Consideration of this device will make it apparent that any element of signal picked up by 21 will be transferred to the line L_2 as an element of one-half the duration of the time required for it to enter upon the path 20. This obviously entails also a doubling of each and every frequency component. The signal currents issuing from this device will thus correspond to the original modulated message at point 1—1 in Fig. 1, but with alternate elements omitted. These omissions will follow each other at a frequency higher than the original message frequency but substantially lower, as explained above, than the frequency of the modulated message. These interruptions or omissions are represented on the line L_2 by modulation frequencies, the fact that these are present being indicated by the legend $(p+f\pm nq)$. These modulation frequencies may be partly eliminated by a band filter 23, this filter being adjusted to pass the band p to $p+f$, as indicated by the single reference $p+f$, it being understood that f takes on substantially all values from zero to 5,000. In order to hear the message, it is now necessary to demodulate it, and for this purpose a demodulator DM is shown, supplied by the incoming signal and by a carrier wave of frequency p from the oscillator O′. The output of this demodulator will consist of the original message with interruptions (so far as not already eliminated by filter 23) at a frequency above the message frequency and these interruption frequencies may therefore be further eliminated by means of a band pass or low pass filter 25, adjusted to transmit only the frequencies f, this being the normal speech message taken in at the transmitting station.

If the modulator and filter of Fig. 1 is not of such a form as to eliminate the carrier component, it will not be necessary to have the oscillator O′ of Fig. 2. In practice, however, the modulator of Fig. 1 may be of the balanced type thus eliminating the carrier or unmodulated component of the wave and then O′ will be necessary. The demodulator of Fig. 2 may also in that event be of the balanced type.

In order to avoid distortion, it is desirable that the picking off of the high frequency wave at 20 shall follow the exact sequence of the original interruptions at 10. The velocity of propagation over paths 20 and 10, and the speed of rotation of arms 21 and 11 should be so related as to reproduce the message segments at their original frequency and the arms should furthermore be in phase at the beginning of each segment, i. e., a form of synchronism should be maintained and any suitable mechanism may be used for this. This means that if arms 21 and 11 are to rotate with equal velocity, the velocity of the wave in 20 should be one half that in 10.

Instead of the path 20 being semi-circular,

it may be circular and then a consideration of the figure will show that the gaps of the resultant message already described will be filled by repetition of the adjacent portions of the message. In this case, the volume of the message received will be increased but there will be more distortion.

While it is to be understood that any suitable form of device may be used in place of the paths 10 and 20, and the pick-up devices 11 and 21, I have shown one form which they may taken on in Figs. 3 and 4. Fig. 3, for example, illustrates a device which might be inserted in the circuit of Fig. 1 between the portions 1—1 and 2—2. Referring to Fig. 3, the frequency $p+f$ may be impressed upon a magnetic winding 30 adjacent to a continuously moving steel tape or wire 31. The incoming message is thus recorded magnetically on this wire which travels with a constant velocity V around a circular path corresponding to the path 10 of Fig. 1. As the wire so travels, it is equivalent to the propagation of the signal wave in that path with the velocity V. A magnetic pick-up or reproducer 32 is mounted on an arm and adapted to rotate adjacent to the magnetized wire and with a velocity $\frac{V}{2}$ in the same direction as that of the wire, thus yielding the results described in connection with Fig. 1.

As a receiving device, Fig. 4 may be substituted for the element shown in Fig. 2 between 3—3 and 4—4. In this case, the converted signal of frequency $\frac{p+f}{2}$ is received on a recording magnet 40, and a magnetic record made on a steel tape or wire 41. This steel tape travels in a manner similar to that described in connection with Fig. 3, but for a half circle only, after which it departs substantially. Adjacent to semi-circular portion and rotating in the opposite direction is a reproducer magnet 42 traveling with a velocity equal to that of the steel tape. As a result, there will be a doubling of the incoming frequency, all as described in connection with Fig. 2. In these figures, devices 34 and 44 are shown to restore the wire to normal condition. These are shown as supplied from a D. C. source but an A. C. source may be used if preferred.

Instead of a moving magnetic tape, many other forms of moving records may be used, such as a phonograph record or a photographic film adapted for recording and reproduction. Still another form the converter may take is shown in Fig. 5 in which the incoming transmission line is continued as a transmission network represented as a pair of conductors forming two concentric circles or two parallel circles with a suitable terminating network 51 which does not give any reflected wave. At the receiving station this path would be a semi-circle.

It is apparent that numerous changes may be made in the particular method of carrying out the invention and in the type of the apparatus used without departing from the spirit of the invention, which I claim to be as follows.

What is claimed is:

1. The method of reducing the width of a band of signaling frequencies during transmission, which comprises modulating the signal train to a carrier frequency, reducing the frequency of successive time elements of the resulting train of waves element by element, transmitting separated portions of the converted wave, translating the received converted wave train portion by portion to a higher frequency, and demodulating the wave to normal signal frequency.

2. The method of reducing the width of a band of signaling frequencies during transmission, which comprises modulating the signal train to a carrier frequency, reducing the frequency of successive time elements of the resulting train of waves element by element, transmitting separated portions of the converted wave in such time relation to each other that no blank intervals will exist, translating the received converted wave train portion by portion to a higher frequency, and demodulating the wave to normal signal frequency.

3. The method of reducing the width of a band of signaling frequencies during transmission, which comprises modulating the signal train to a carrier frequency, interrupting the signal frequency into elements at a frequency substantially different from the carrier frequency, suppressing certain elements, expanding the time duration of the adjacent elements to extend into the time of suppressed elements, transmitting the separated portions, translating the received converted wave train portion by portion to its original shorter duration, and demodulating the wave to normal frequency.

4. The method of reducing the width of a band of signaling frequencies during transmission, which comprises modulating the signal train to a carrier frequency, interrupting the signal frequency into elements at a frequency low compared to the carrier frequency, suppressing certain elements, expanding the time duration of the adjacent elements to extend into the time of suppressed elements, transmitting the separated portions, translating the received converted wave train portion by portion to its original shorter duration, and demodulating the wave to normal frequency.

5. The method of reducing the width of a band of signaling frequencies during transmission, which comprises modulating the signal train to a carrier frequency, interrupting the signal frequency into elements at a frequency intermediate the carrier and the signal

frequency, suppressing certain elements, expanding the time duration of the adjacent elements to extend into the time of suppressed elements, transmitting the separated portions, translating the received converted wave train portion by portion to its original shorter duration, and demodulating the wave to normal frequency.

6. The method of reducing the width of a band of signaling frequencies during transmission, which comprises modulating the signal train to a carrier frequency, interrupting the signal frequency into elements at a frequency intermediate the carrier frequency and the signal frequency, suppressing certain elements, expanding the time duration of the adjacent elements to occupy the time of the suppressed elements and in such time relation to each other that no blank intervals will exist, transmitting the separated portions, translating the received converted wave train portion by portion to its original shorter duration, and demodulating the wave to normal signal frequency.

7. In a transmission system. a transmitting station, means thereat for reducing the width of a band of signaling frequencies during transmission comprising a source of signals to be transmitted, means for modulating the signal to a carrier frequency, means for interrupting the modulated carrier wave into elements and narrowing the frequency range.

8. In a transmission system, a transmitting station, means for reducing the width of a band of signaling frequencies comprising a source of signals to be transmitted, means for modulating the signal to a carrier frequency, and means for interrupting the modulated carrier wave at a frequency substantially below the carrier frequency.

9. In a transmission system, a transmitting station, means for reducing the width of a band of signaling frequencies comprising a source of signals to be transmitted, means for modulating the signal to a carrier frequency and for suppressing all but one side band, and means for interrupting the said side band at a frequency substantially below the carrier frequency.

10. In a transmission system, a transmitting station, means for reducing the width of a band of signaling frequencies comprising a source of signals to be transmitted, means for moduating the signal to a carrier frequency, means for interrupting the modulated carrier wave at a frequency substantially below the carrier frequency, a receiving station, a frequency expanding means associated therewith for expanding the received wave train to normal frequency width, and means for demodulating the resultant wave to normal signaling frequency.

11. In a transmission system, a transmitting station, means for reducing the width of a band of signaling frequencies comprising a source of signals to be transmitted, means for modulating the signal to a carrier frequency, means for interrupting the modulated carrier wave at a frequency substantially below the carrier frequency, a receiving station, a frequency expanding means associated therewith for expanding the received wave train to normal frequency width, means for demodulating the resultant wave to normal signaling frequency, and wave filters at the receiving station for eliminating the interrupter and expander modulation frequencies.

12. In a signaling system, means for reducing the width of a signal frequency band, comprising a moving record, means for recording the signal thereon, and a moving pick-up device adjacent to said record having a uniform velocity different from the velocity of the record and moving always in the same direction as the record.

13. In a signaling system, means for contracting the width of a signal frequency band, comprising a moving iron tape or wire, a magnetic recording means adjacent thereto, a magnetic pick-up device adjacent to said tape or wire and having a uniform velocity different from the velocity of the tape or wire and moving always in the same direction as the tape or wire.

14. In a transmission system, a transmitting station, means thereat for reducing the width of a band of signal frequencies during transmission, comprising a source of signals to be transmitted, means for modulating the signal to a carrier frequency, and means for suppressing alternate elements of the modulated carrier wave and expanding the time duration of the other elements.

15. In a transmission system, a transmitting station, means thereat for reducing the width of a band of signal frequencies during transmission, comprising a source of signals to be transmitted, means for modulating the signal to a carrier frequency, means for suppressing alternate elements of the modulated carrier wave and expanding the time duration of the other elements, a receiving station, and means at that station for compressing the received expanded elements to their normal duration.

16. In a transmission system, a transmitting station, means thereat for reducing the width of a band of signal frequencies during transmission, comprising a source of signals to be transmitted, means for modulating the signal to a carrier frequency, means for suppressing alternate elements of the modulated carrier wave and expanding the time duration of the other elements, a receiving station, means at that station for compressing the received expanded elements to their normal duration and for repeating each element to fill up the time spaces.

17. In a signal transmission system, a

transmitting station, means thereat for reducing the width of a band and signal frequencies during transmission, comprising a source of signals to be transmitted, and means for suppressing alternate elements of the signal and expanding the time duration of the other elements.

18. In a transmission system, a transmitting station, means thereat for reducing the width of a band of signal frequencies during transmission, comprising a source of signals to be transmitted, means for suppressing alternate elements of the signal train and expanding the time duration of the other elements, a receiving station, and means at that station for compressing the received expanded elements to their normal duration.

19. In a signal transmission system, a transmitting station, means thereat for reducing the width of a band of signal frequencies during transmission, comprising a source of signals to be transmitted, means for suppressing alternate elements of the signal train and expanding the timed duration of the other elements, a receiving station, means at that station for compressing the received expanded elements to their normal duration and for repeating each element to fill up the time spaces.

20. In a signal system comprising a transmitting and a receiving station, means at the transmitting station for contracting the width of the signal frequency band comprising a moving record, means for recording the signal thereon and a moving pick-up device adjacent to said record having a velocity different from the velocity of the record and moving always in the same direction as the record, and means at the receiving station for expanding the width of the received frequency band, comprising a moving record, means for recording the received signal thereon, and a moving pick-up device adjacent to said record having a uniform velocity and moving always in the opposite direction to the record.

In testimony whereof, I have signed my name to this specification this 11th day of August, 1926.

ALLEN CARPE.