Sept. 8, 1931. W. T. WINTRINGHAM 1,821,997

COMPRESSION OF FREQUENCY RANGE

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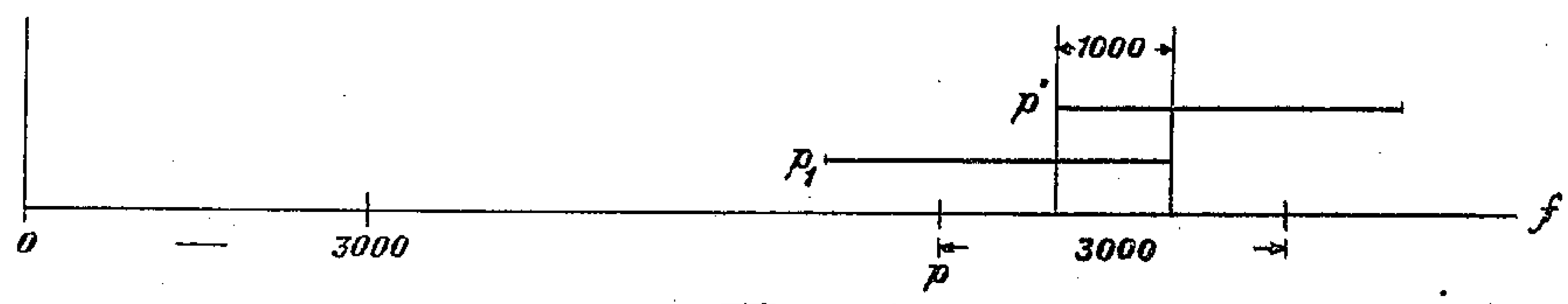

Fig. 1

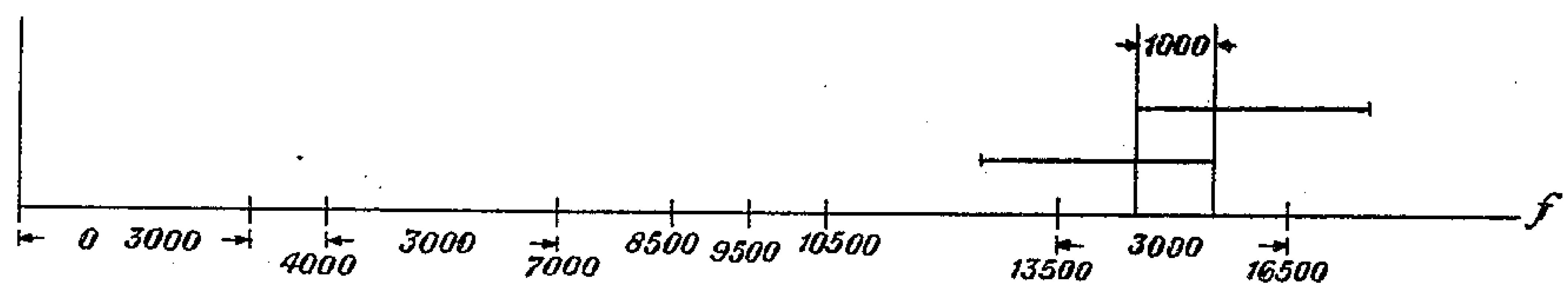

Fig. 2

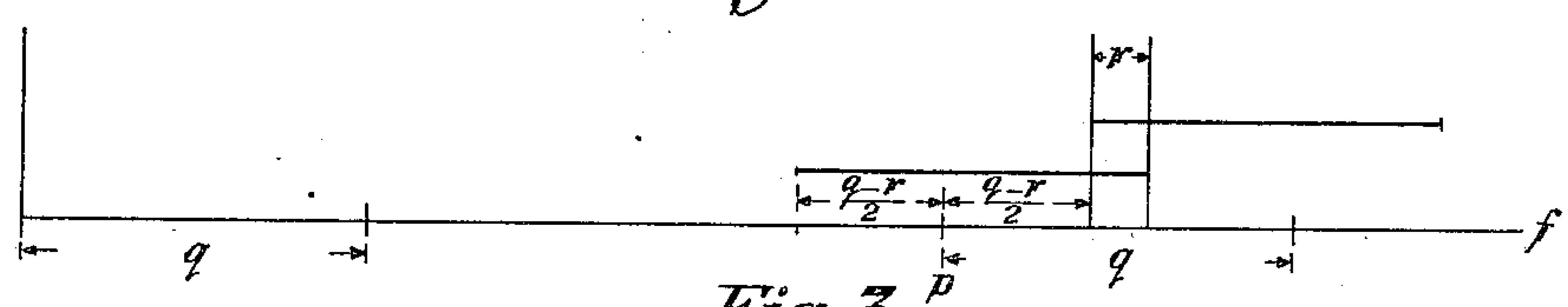

Fig. 3

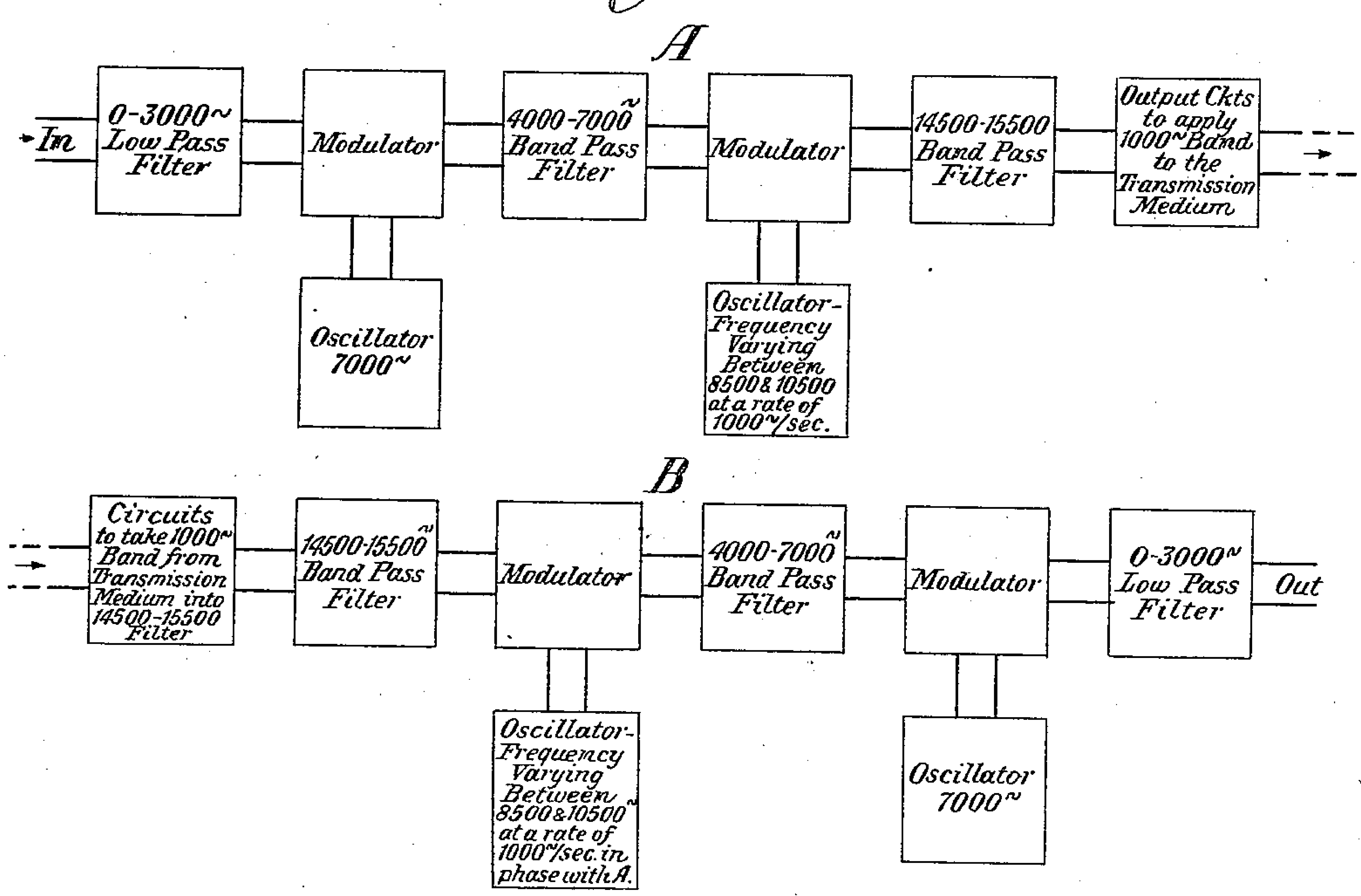

Fig. 4

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COMPRESSION OF FREQUENCY RANGE

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This invention relates to a method and means for compressing the frequency range required for signaling. Its purpose is to make possible an increase in the number of channels of communication over any transmission system. Another purpose is to obtain a greater measure of secrecy in communication than is now commonly present.

It is well recognized that if a plurality of messages are to be transmitted simultaneously over any transmission medium, the frequency bands of the several messages should not overlap. In order, then, to obtain as large a number of channels as possible over a given transmission medium, it is desirable that the frequency band width for each signaling channel should be as narrow as possible, in order that F times T shall be as small as feasible where F represents the width of the signaling band and T the time required to transmit the message.

In this invention I propose to accomplish the desired ends by transmitting a given portion of the message frequency band for a portion of the time only and arranging the system so that the portion of the band which is being transmitted shall move from one end of the signaling band to the other periodically, thus giving opportunity for all frequency bands in the desired range to be represented, but for a portion of the time only. This make its possible to reduce the width of the band during transmission and still transmit the message at the normal rate. More specifically, I practice my invention by modulating a periodically varying carrier frequency with the message to be transmitted. One side band of the modulation products, which band will have the same width as the original message, is then reserved and a portion of this side band only is transmitted. In view of the varying nature of the carrier frequency, it is possible to give each portion of the original signal a representation in the narrow portion of the side band which is finally transmitted.

At the receiving station, this narrow side band is demodulated by a locally generated carrier frequency which varies in the same manner and in phase with that at the transmitting station. Among the demodulation products there will appear an original message with which the varying carrier at the transmitting station was modulated.

The invention will be better understood by reference to the accompanying drawing in which Figures 1, 2 and 3 show frequency spectra, and Fig. 4 shows a signaling system embodying my invention. Referring more particularly to Fig. 1, the abscissæ represent the frequency and, for purposes of illustration, I have assumed a message such as a speech signal whose frequency band extends from 0 to 3,000 cycles. Suppose now, this message is used for modulating a carrier frequency p. Of the two side bands, one is suppressed, and in Fig. 1, I have shown the upper band extending from p to $p+3{,}000$ as being reserved. By suitable means, such as band filters, any desired portion of this upper side band may be transmitted, and in Fig. 1 I have shown this band as being of width 1,000 and being in the middle of the carrier side band. If the carrier frequency were to remain fixed, then a portion only of the original message would be transmitted, the upper third and the lower third having no representation. If, however, the carrier frequency should be lowered to p_1 by an amount equal to one-third the width of the 3,000-cycle band, then it is evident that through the same band filter the upper third only of the original signaling frequency band would be transmitted. On the other hand, if the carrier frequency were increased to p' by an amount equal to one-third the width of the signaling band, then the lower third of the original signaling band would be represented in the wave passing through the band filter. Still further, if the carrier frequency were to vary continuously from p_1 to p' and back again, then at one time or another each and every portion of the original signal band would be represented in the output of the band filter.

My invention, then, consists in part in providing means for varying the carrier frequency by a suitable amount, so that each portion of the original message shall receive representation. This variation may take place in any desired manner, that is, continuously or step by step. In the continuous change, again, it is evident that the variations may follow a large variety of current relations. That is, the frequency may vary at a uniform rate from p_1 to p' and back again, or may vary between these limits sinusoidally, or in any other desired manner, certain ones being preferable to certain others. In actual practice, I would prefer to have a uniform rate of frequency change in passing from p_1 to p' and then the same uniform rate in passing from p' to p_1.

In general, such modulation on a varying carrier frequency will introduce certain modulation products whose frequencies may lie in the range of the message frequency. It will be desirable to avoid this, and Fig. 2 represents a modification of the invention for this purpose. In that case again, definite values for frequencies have been used for illustrative purposes, but it is to be understood that the invention is not restricted to the particular frequencies indicated. Referring to that figure, the message signal whose frequencies vary from 0 to 3,000 is first modulated on a fixed carrier frequency such as 7,000 cycles. One of the side bands from this modulation is reserved, in this case the lower side band extending from 4,000 cycles to 7,000 cycles. The second carrier frequency is shown as having a mid-value for p of 9,500 and varies as a whole from the value for p_1 of 8,500 to a value for p' of 10,500. This varying carrier is now modulated with the band extending from 4,000 to 7,000, and the upper side band only is retained, this band extending from 13,500 to 16,500 when $p=9{,}500$. Here, also, for illustrative purposes, the middle third of this upper band is transmitted, and it will be seen, as in the case of Fig. 1, that at one time or another all portions of the original signal band are represented.

The invention may be carried out with apparatus shown schematically in Fig. 4, in which A represents the transmitting station and B the receiving station. In this figure, the apparatus indicated schematically corresponds to the system described in connection with Fig. 2. The input band of frequencies extending from 0 to 3,000 cycles is transmitted through a low-pass filter to eliminate any extraneous frequencies. It is then modulated on a carrier frequency of 7,000 cycles, and the lower side band from 4,000 to 7,000 cycles is selected from the output of the modulator by band pass filter. As has been previously mentioned, the purpose of this modulation is to eliminate undesired modulation components at later stages. From the output of this band filter, the band is put into a modulator the carrier frequency of which varies from 8,500 to 10,500 cycles. The rate at which the carrier frequency is varied is subject to a wide latitude of choice but preferably should be of a reasonably high rate in order that no portion of the original frequency band shall be omitted for a long period of time. A very suitable condition would be to have the frequency of the oscillator go through its cyclic change at a rate of 1,000 cycles per second. In the output of this modulator there is a band pass filter passing the band 14,500 to 15,500 cycles, that is, a band whose width is 1,000 cycles, which, it will be seen, lies in the middle portion of the upper side band resulting from the second modulation. The output of this band pass filter is then impressed upon the transmission medium by means of any appropriate circuits.

Comparing the results thus far obtained, it will be seen that when the second carrier frequency is at its lowest value of 8,500, the band transmitted corresponds to the frequencies from 6,000 to 7,000 in the intermediate modulation side band, which in turn corresponds to the frequencies from 0 to 1,000 in the original message band. Similarly, the portion of the band which is transmitted for any other value of carrier frequency can be calculated. For convenience, the following table shows the results at a number of different values:

Carrier frequency	Equivalent input band of intermediate side band	Equivalent input band of original band
8,500	7,000–6,000	0–1,000
9,000	6,500–5,500	500–1,500
9,500	6,000–5,000	1,000–2,000
10,000	5,500–4,500	1,500–2,500
10,500	5,000–4,000	2,000–3,000

Since in this case the carrier is varied between the limits 8,500 and 10,500 at the rate of 1,000 cycles per second, in the period of one two-thousandths of a second each frequency in the original input band would have been transmitted through the 14,500 to 15,500 cycle band filter for a fraction of the time, and thus every part of the original frequency band will have been represented. The band of frequencies at the output of the last band filter mentioned may be either transmitted over a circuit in this position in the frequency spectrum or may be shifted by modulation into any other band of 1,000 cycle width that may be desirable.

At the receiving end, the 1000-cycle band should preferably be remodulated to the position 14,500 to 15,000 cycles if it has been shifted and then impressed on another modulator having a varying carrier frequency extending between the same limits of 8,500 and 10,500, at the same rate of 1,000 cycles per second and supplied in the proper time phase. The time phase is important, since the remodulated carrier must be at exactly the correct frequency at each instant to remodulate the output band into a normal speech band. At the output of this modulator, the side band 4,000 to 7,000 cycles is selected by a band pass filter shown in the receiving circuit of station B, and in turn is modulated on a carrier of 7,000 cycles to shift the band to its original position from 0 to 3,000 cycles and being preferably transmitted through a low pass filter to again eliminate any extraneous frequencies.

While the circuit of Fig. 4 has been described in connection with definite values of frequencies, it is to be understood that the invention is not limited to these frequencies and that the width of the band to be finally transmitted may be modified over a wide range. This can be made clear by a reference to Fig. 3 in which, for simplicity, the intermediate frequency modulation has been omitted. In this Fig. 3, the original signal band is shown as extending over a width q starting with zero. This is modulated against a varying carrier frequency whose mid-value is p. Selecting the upper side band, it is seen that this extends from p to $p+q$, and in the middle of this band there is selected for transmission a narrow band of width r. If, now, the carrier frequency is reduced to the value

$$p-\frac{q-r}{2},$$

the upper portion of the original band is represented, whereas when the carrier frequency is shifted to

$$p+\frac{q-r}{2},$$

the lower portion of the original band is represented, and for intermediate values of the carrier frequency, intermediate portions of the original band are represented.

While in this description I have assumed that the upper side band is retained after modulation by the varying frequency, it should be pointed out that the lower side band could have been retained and upon similar demodulation at the receiving station the message would reappear in correct form. Also, while in Fig. 2 the original message is shown as being shifted to the band 4,000 to 7,000, which is below the varying frequency, it could have been shifted to a band above the varying frequency, whereupon by suitable demodulation and shifting of the band the original message would reappear in its correct spectral position. Many other variations may also be introduced as to the side bands which will be retained or as to the particular apparatus used for carrying out the invention, all leading to substantially the same results, and it is to be understood that they are included in this invention.

What is claimed is:

1. The method of signaling, which consists in transmitting a narrow band of frequencies of definite width which represents successively different portions of the original message band and suppressing all other frequencies.

2. The method of signaling, which consists in transmitting a band of frequencies narrower than that of the message, the narrow band representing successively different portions of and covering the band width of the original message to be transmitted.

3. In a signaling system, the method of signaling with a reduced frequency band width, which consists in modulating the message to a carrier wave of periodically varying frequency and transmitting a portion of the modulated wave band of a width less than the band width of the original message to be transmitted and suppressing the remainder.

4. In a signaling system, the method of signaling with a reduced frequency band width, which consists in modulating the message to a carrier wave of periodically varying frequency, transmitting a portion only of the modulated wave band of a width less than the band width of the original message to be transmitted, suppressing the remainder, and demodulating this wave at the receiving station with a similarly periodically varying carrier frequency.

5. In a signaling system, the method of reducing the signal frequency band of width q to one of a narrower width r, which consists in modulating the message to a carrier wave of mid-frequency p and varying the carrier frequency over a range from

$$p+\frac{q-r}{2} \text{ to } p-\frac{q-r}{2}$$

and suppressing all frequencies except those in the band of width r.

6. In a signaling system, the method of transmitting a message of frequency band width q by one of a narrower width r, which consists in modulating the message to a carrier wave of mid-frequency p, varying the carrier frequency over a range from

$$p+\frac{q-r}{2} \text{ to } p-\frac{q-r}{2},$$

transmitting the band of width r and demodulating this at the receiving station with a carrier of the same varying frequency maintained in a definite phase relationship with the carrier of the transmitting station.

7. In a signaling system for signaling with a reduced frequency band width, a source of signal current, a generator of carrier oscillations of varying frequency,

means for modulating the carrier with the signal, means for transmitting a portion of the modulated frequency band narrower than the message band width, a receiving station, a generator of carrier oscillations of a similarly varying frequency, and means for demodulating the received signal on the said oscillations to substantially reproduce the original message.

8. In a system for transmitting a message of frequency band width q, means for reducing the band width to a band of width r during transmission, said means comprising an oscillation generator for carrier current of frequency varying periodically by the amount $q-r$, means for modulating the varying carrier with the message, means for selecting from the modulated side band a band of width r, a receiving station and means thereat for reversing the process to yield the message of band width q.

9. The method of reducing the frequency band width required for transmitting a message of a definite band width, which consists in transmitting at one time a portion only of the message frequency band and varying this portion cyclically throughout the range of the message frequency band.

10. The method of reducing the frequency band width required for transmitting a message of a definite band width, which consists in shifting the message band cyclically across a definite frequency range and suppressing all but a band narrower than the shifted message band width.

11. The method of signaling on a reduced frequency band width, which consists in modulating the signal to a varying carrier frequency, transmitting a portion of one side band thereof of narrower frequency than the message band width, and performing the reverse process at the receiving station to yield a message of original band width.

12. A signaling system for signaling with reduced band width a message to be transmitted of a certain frequency band width, means for suppressing all but a narrow band of width less than that of the message to be transmitted, and means for causing the whole band to shift periodically over a definite frequency range to permit representation in said narow band of each part of the original message frequency band to be transmitted.

In testimony whereof, I have signed my name to this specification June, 1929.

WILLIAM T. WINTRINGHAM.