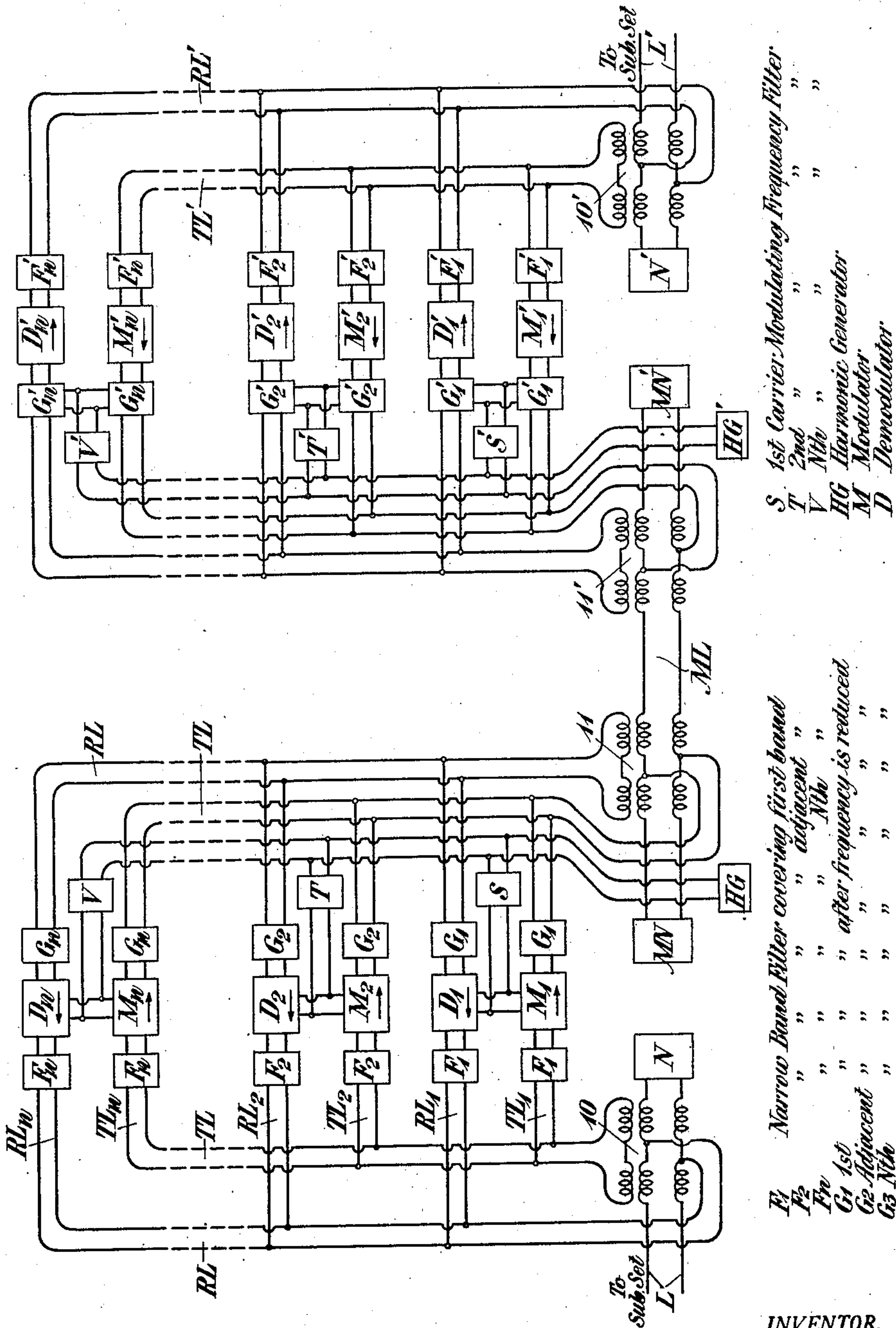


Oct. 6, 1925.

1,555,916

L. ESPENSCHIED
FREQUENCY TRANSLATING SYSTEM
Filed Oct. 25, 1922



S 1st Carrier Modulating Frequency Filter
T 2nd " " "
V Nth " " "
HG Harmonic Generator
M Modulator
D Demodulator

F1 Narrow Band Filter covering first band
F2 " " " " adjacent " "
F3 " " " " Nth " "
G1 1st " " after frequency is reduced
G2 Adjacent " " " "
G3 Nth " " " "

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FREQUENCY-TRANSLATING SYSTEM.

Application filed October 25, 1922. Serial No. 596,833.

To all whom it may concern:

Be it known that I, LLOYD ESPENSCHIED, residing at Hollis, in the county of Queens and State of New York, have invented certain Improvements in Frequency-Translating Systems, of which the following is a specification.

This invention relates to wave transmission systems, and more particularly to transmission of the energy of given waves or impulses by means of waves of lower frequency than those whose energy is to be transmitted.

An important field of electric transmission is that involving the use of unidirectional or alternating currents modified in certain of their characteristics, such as continuity, intensity or frequency. In this field, which includes electric signaling and other teledynamic electric operation, efficiency from an energy standpoint is important, but is frequently much less important than faithful transmission of the wave forms involved. In the case of telephony there is involved transmission of a wide range of essential frequencies, and it is desirable that these frequencies be transmitted without distortion and without utilizing undue range of the frequency spectrum of the transmission medium employed.

In accordance with the method of the present invention these difficulties are overcome by the reduction of the effective frequencies of the currents to be transmitted, so that they may be transmitted over circuits of limited frequency range, or, in the case of transmitting media having larger frequency ranges, without utilizing an unnecessarily wide band of the frequency range available. Since the transmission of speech involves waves extending through a wide band of frequencies, it is necessary, if the intelligibility and naturalness of the speech are to be preserved, to make the transmission such as to retain, so far as possible, each of the initial frequency elements. Where the highest essential frequency elements exceed the upper limit of the frequency transmission range of the circuit, successful transmission thereover is not possible. The object of the present invention is to effectively reduce the frequencies of the

various components of a band of currents so as to make them fall within the transmission range of commercial transmission circuits.

In the case of certain types of signaling bands, such, for example, as a band of telephone frequencies, it may not be necessary or even desirable to transmit all of the frequencies within the limits of the band. In other words, the original band may be thought of as not being continuous but consisting of a number of smaller subbands separated by blank or unessential frequency intervals. Where such is the case, it is proposed, in accordance with the present invention, to so operate upon the lowest frequency subband as to subtract from the frequency of each of its components the original frequency of its lowest frequency component, thus reducing the subband to a range of frequencies from zero to a new upper limiting frequency. At the same time there may be subtracted from the frequency of each component of the second or next highest subband a frequency sufficient to reduce its lowest frequency component to approximately the new upper limiting frequency of the first subband. The third subband may be similarly reduced in frequency so as to make its lowest frequency approximately that of the highest frequency of the reduced second band. A similar treatment may be applied with respect to each subband with the final result that a continuous band will be obtained extending from zero to a fixed upper limit much lower than the upper limiting frequency of the original band of frequencies. This continuous band may be transmitted, and after transmission may be separated into its various subbands, and each subband may be stepped up in frequency to its original frequency position.

By treating a band of signaling frequencies in the manner previously described, the range of frequencies heretofore necessary for the transmission of telephonic signals, for example, may be encompassed for transmission purposes within a very much narrower frequency range without any inherent distortion in the signal itself. This not only enables the use of a circuit having rela-

tively small frequency range for the purpose of transmitting a signal involving a much wider frequency range, but also renders it possible to so efficiently utilize the frequency spectrum available in the case of a radio or wire carrier system as to permit of superposing a larger number of carrier channels upon a given transmitting circuit than has heretofore been considered practicable. Another advantage of the method of transmission herein disclosed is that the translation and squeezing together of the component frequencies and subbands of frequencies produce a frequency combination during transmission over the main transmitting medium which will not produce an intelligible effect on ordinary receiving instrumentality. In other words, the method of the present invention is essentially one in which a high degree of secrecy is obtainable.

In order to understand how the results of the present invention are obtained, it should be remembered that the modulation of a carrier wave by waves of a band of frequencies is to produce two so-called "side bands." See, for example, the article entitled "Carrier current telephony and telegraphy" by Colpitts and Blackwell, pages 307 to 310 inclusive, Journal of the American Institute of Electrical Engineers, vol. 40, April 1921, No. 4. Of these two bands the upper side band may be considered as the original band of waves having the frequency of each of its components increased by the carrier frequency. Since instead of a high carrier frequency, there may be impressed upon the modulator a frequency changing wave of any definite frequency, it is obviously possible to increase the effective frequencies of each component of the band by this definite amount. If the frequency of the wave applied to the modulator is lower than that of the lowest component of the original band, the lower or difference frequency side band resulting from the modulating action may be considered as the original band with its component frequencies each reduced by the definite frequency. There are accordingly available simple methods of stepping up the frequency of bands of waves or stepping them down at will.

The operation of both modulators and demodulators may be looked upon as that of frequency changes. The modulator operates to change the frequency by the frequency of the so-called "carrier" wave applied thereto. The demodulator in general changes the frequency of a band of modulated wave components by the frequency of the unmodulated carrier wave component which is usually present with the side bands. In both instances upper and lower side bands are produced by the frequency changing operation, and it is necessary to select the desired

side band by means of filters or other selective circuits.

With these principles in mind, it will be obvious that the results sought by the present invention may be obtained by selecting the essential subbands of the wider frequency band to be transmitted in the individual circuits translating the frequencies of the subbands by modulating them with carrier frequencies so chosen as to step each subband down to such a position in the frequency spectrum that all of the subbands will occupy a narrower frequency range extending from zero up to the maximum frequency of the upper stepped down subband. The waves may now be transmitted in this condition, and at the receiving end of the system the component subbands may be again selected into individual circuits by means of suitable filters and by a process of modulation each subband may be again restored to its original position in the frequency spectrum. The restored subbands when applied to an ordinary receiving instrument will produce substantially the same effect, except for some possible loss of articulation, as though the original frequency band had been applied to the receiving instrument without undergoing any frequency translation.

The invention may now be more fully understood from the following detailed description thereof when read in connection with the accompanying drawing, the figure of which illustrates in a simplified and schematic form the circuit elements necessary to carry out the process of the invention.

Referring to the drawing, L designates an ordinary telephone transmission line terminating in the usual form of subscriber's substation set. At the other end the line terminates in the usual type of hybrid coil 10 and balancing network N. A common transmitting circuit TL and a common receiving circuit RL may be associated with the line L through the hybrid coil 10, and individual transmitting and receiving channels are associated with the main transmitting and receiving circuits TL and RL, as indicated by the characters TL_1 , TL_2 , etc., which designate the individual transmitting channels, and the characters RL_1 , RL_2 , etc., designate the individual receiving channels. The individual channels at their opposite ends are again combined in the common transmitting and receiving circuits TL and RL, which are associated by means of a hybrid coil 11 and balancing network MN with the main transmission line ML. The subscript 1 applied to a piece of apparatus or a channel in the drawing indicates that that piece of apparatus or channel is used in connection with the lowest subband of the larger band of frequencies to be transmitted. Similarly, the subscript 2 has refer-

ence to a piece of apparatus or a channel utilized in connection with the next lowest subband, and the subscript "n" refers to a piece of apparatus or a channel used in connection with the highest subband of the main band to be transmitted.

In order to select the lowest transmitted subband into the channel TL_1 , a filter F_1 is provided, said filter being, for example, of the well known Campbell type and having cut-off points coinciding with the limiting frequencies of the lower subband. For the purpose of transmitting the selected band of frequencies into a range extending from zero upward, a modulator M_1 is provided. This modulator may, for example, be of the type disclosed in Carson, Serial No. 1,343,307, of June 15, 1920. The modulator is provided with a carrier frequency equal to the lowest frequency of the selected subband through a filter S in a manner to be described hereafter, and by beating the selected band with said carrier frequency, two side bands are produced, an upper and a lower side band. The lower side band will include frequencies corresponding to the individual frequencies of the original subband selected, but these frequencies, while extending over a range of equal width, will extend from zero up to a finite frequency, instead of from one finite frequency to another finite frequency. In order to select this lower band from the upper side band, a filter G_1 is provided. This filter may be of the Campbell type, and its cutoff points are so chosen that it will transmit a band extending from zero up to the upper limit of the translated subband of frequencies. In a similar manner, the transmitting channel TL_2 is provided with filters F_2 and G_2 and a modulator M_2 . These pieces of apparatus are similar to those already described in connection with the channel TL_1 , except that the filter F_2 selects the next important subband of frequencies above the subband selected by the filter F_1 , and the filter G_2 selects a band of the same width as that selected by the filter F_2 , but extending upward from the upper limit of the band selected by the filter G_1 instead of extending upward from the lower limit of the original subband selected into the channel TL_2 . The modulator M_2 is provided with a carrier frequency through the filter T , the frequency of said carrier being so chosen as to produce a lower side band corresponding to the transmission range of the filter G_2 . In a similar manner the transmitting channel TL_n is provided with filters F_n and G_n as well as the modulator M_n . The filter F_n selects the upper component subband of the main band to be transmitted. The modulator M_n steps it down in frequency, and the filter G_n selects the stepped down frequency subband. Consequently there will be impressed upon the main line

ML through the hybrid coil 11 a frequency band having frequencies corresponding to the essential frequencies in all of the main component bands of the original band to be transmitted. This stepped down band will, however, occupy a much narrower range than that of the original band.

The receiving channel corresponding to each transmitting channel will include filters having the same characteristics as corresponding filters in each transmitting channel, and, in addition, the demodulators D_1 , D_2 and D_n will be provided in the receiving channel. The filters G_1 , G_2 , etc., select the component subbands in the translated frequency band transmitted over the main line ML and impress the individual translated band selected upon the corresponding demodulators. Each demodulator, which may be of the type disclosed in Carson Patent 1,343,308 of June 15, 1920, has applied to its input circuit a carrier frequency which is the same as the carrier frequency applied to the corresponding modulator. The operation of demodulation results in producing a side band having frequencies corresponding to the band impressed upon the demodulator but differing therefrom in that each component frequency of the side band is higher than the frequency to which it corresponds by an amount equal to the carrier frequency applied to the demodulator. This side band, which corresponds to the original subband of the main band transmitted at the distant station, will be selected by the band filter F_1 or F_2 , etc., as the case may be. Consequently, stepped up subbands corresponding to the essential subbands of the original messages will be combined in the receiving circuit RL and will be transmitted to the subscriber's line L .

While individual sources may be employed for supplying the carrier frequency to each modulator and its corresponding demodulator, it is preferred, where possible, to employ a harmonic generator, schematically indicated at HG , for the purpose of producing carrier frequencies which are harmonics of some fundamental base frequency, the desired harmonics being selected and transmitted to the proper modulator and demodulator by means of filters such as S , T and V . These filters are preferably simple tuned circuits of a type well known in the art. The harmonic generator HG is also a well known piece of apparatus and is fully described in the Colpitts-Blackwell paper previously referred to.

The apparatus so far described may be located at one terminal of the main transmission line ML , or other medium which is employed for transmission between two distant points. At the distant end a similar equipment will be provided as indicated in the drawing, its corresponding elements be-

ing represented by the same reference characters as those already described, except that the reference characters are primed.

The operation of the circuit as a whole will, of course, be obvious from description of the operation already given in connection with the elements of the circuit. It will be noted, however, that for transmission from the substation set of the line L to the substation set of the line L', a normal band of frequencies will be transmitted over the line L and translated into a narrower band of lower frequency before being applied to the main line ML. The band of frequencies translated over the main line ML, being a narrower band and of lower frequency than the original band transmitted over the terminal line L, therefore differs from the band transmitted over the main line of a carrier transmission circuit, as in the latter case the translation is upward with a consequent increase in the frequency without any attempt being made to narrow the band corresponding to a given signaling channel. The narrowed band transmitted over the main line by the arrangement of the present invention is at the transmitting station expanded and translated into a band of frequencies corresponding to the original band in a manner obvious from the description of the receiving apparatus already given, the expanded band being transmitted over the line L' to the distant subscriber's set. It will also be observed that the band of frequencies transmitted over the line ML will, because of the translation in frequency and because of the narrowing of the band be substantially unintelligible, thereby rendering it difficult for unauthorized persons to tap the circuit.

The system as described has reference to the transmission of the signal from a single channel over a main line such as ML. The scheme is applicable, however, to either carrier transmission over wires or carrier transmission by radio. In either of these cases the narrowed band, which in the case illustrated is applied to the line ML, will be applied to the modulating channel of the wire carrier or radio carrier apparatus, and at the receiving station the band detected by the demodulator of the carrier system, whether wire or radio, will correspond to the narrowed band received from the main line ML in the case described. Consequently, the detected band in the carrier system will be impressed upon a receiving arrangement like that already described. As the invention proper is entirely independent of the type of transmitting medium employed in lieu of the line ML, it is unnecessary to illustrate the same in connection with carrier equipment.

It will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different

from those illustrated without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. The method of transmitting a band of waves over a conducting path which offers an excessive transmission loss to the higher frequency components thereof which method comprises reducing the frequencies of all of the components to frequencies well within the efficient transmission range of said path.

2. The method of transmitting the essential elements of a broad band of waves over a circuit having a practical transmission range of more limited extent than said band which comprises selecting the essential elements of said band, producing therefrom a continuous band of an extent lying within the transmission range of said circuit, transmitting said continuous band over said circuit and restoring each of the elements thereof to its original frequency position.

3. The method of transmitting a band of waves lying between two definite frequency limits over a conductor within the transmission range of which one of said limits does not fall which method comprises reducing the frequencies of each component of said band by predetermined amount to cause said frequency limits to fall within said transmission range, transmitting said reduced frequency band over said conductor and thereafter increasing the frequency of each of the transmitted components by the same predetermined amount by which it was reduced before transmission.

4. The method of two-way transmission between two stations which comprises operating at each station upon the waves to be transmitted to the other station before transmission in such manner as to reduce the effective frequencies of each of the components thereof and operating at each station upon waves received from the other station to increase the frequency of each component thereof by the amount of the previous decrease.

5. A transmission system for transmitting a band of waves over a conducting path which offers excessive transmission loss to the higher frequency components thereof, comprising means for reducing the frequencies of all of the components of said band to frequencies well within the efficient transmission range of said path.

6. A system for transmitting the essential elements of a broad band of waves comprising a circuit having a practical transmission range of more limited extent than said band, means for selecting the essential elements of said band, means for producing from said selected elements a continuous band of an extent lying within the transmission range of said circuit, means for transmitting said continuous band over said circuit, and means

for restoring each of the elements transmitted thereover to its original frequency position.

5 7. In a system for transmitting a band of waves lying between two definite frequency limits over a conductor within the transmission range of which one of said limits does not fall which comprises means for reducing the frequency of each component of said
10 band by a predetermined amount to cause said frequency limits to fall within said transmission range, means for transmitting said reduced frequency band over said conductor to a distant station, and means at
15 said station for increasing the frequency of each of the transmitted components by the same predetermined amount by which it was reduced before transmission.

20 8. The method of electrically transmitting intelligence which consists in reducing the frequency range represented by the signal

currents, transmitting the reduced range of frequencies over a translating medium and restoring the transmitted range of frequencies to the original range of frequencies. 25

9. The method of electrically transmitting intelligence, which consists in selecting the essential component subbands of a main band of frequencies corresponding to a signal, translating the frequencies of the selected subbands to produce corresponding bands which are contiguous, selecting the component bands after transmission and restoring the frequencies of the selected subbands to those of the original subbands to produce
30 a range of frequencies corresponding to the original range. 35

In testimony whereof, I have signed my name to this specification this 24th day of October, 1922.

LLOYD ESPENSCHIED.